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INTERNATIONAL NUMERICAL MULTIPLE AND SUBMULTIPLE PREFIXES

Multiples and submultiples	Prefixes	Symbols	Pronunciations
10^{12}	tera	T	tĕr' a
10^{9}	giga	G	jĭ' ga
10^{6}	mega	M	mĕg' a
10^{3}	kilo	k	kĭl' o
10^{2}	hecto	h	hĕk' to
10	deka	da	dĕk' a
10^{-1}	deci	d	dĕs' i
10^{-2}	centi	c	sĕn' ti
10^{-3}	milli	m	mĭl' i
10^{-6}	micro	μ	mi' kro
10^{-9}	nano	n	năn' o
10^{-12}	pico	p	pē' co
10^{-15}	femto	f	fĕm' to

SYMBOLS, UNITS, AND EQUIVALENTS

Symbol	Unit	Equivalent
BeV	billion electron volts	GeV
Ci	curie	3.7×10^{10} dps
cm	centimeter(s)	0.394 inch
cpm	counts per minute	
dpm	disintegrations per minute	
dps	disintegrations per second	
eV	electron volt	1.6×10^{-12} ergs
g	gram(s)	
GeV	giga electron volts	1.6×10^{-3} ergs
kg	kilogram(s)	1,000 g = 2.205 lb
km^2	square kilometer(s)	
kVp	kilovolt peak	
m^3	cubic meter(s)	
mA	milliampere(s)	
mCi/mi^2	millicuries per square mile	0.386 nCi/m^2 (mCi/km^2)
MeV	million (mega) electron volts	1.6×10^{-6} ergs
mg	milligram(s)	
mi^2	square mile(s)	
ml	milliliter(s)	
mm	millimeter(s)	
nCi/m^2	nanocuries per square meter	2.59 mCi/mi^2
pCi	picocurie(s)	10^{-12} curie = 2.22 dpm
R	roentgen	
rad	unit of absorbed radiation dose	100 ergs/g

RADIOLOGICAL HEALTH DATA AND REPORTS

Volume 9, Number 3, March 1968

In August 1959, the President directed the Secretary of Health, Education, and Welfare, to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels such as natural background, radiography, medical and industrial uses of isotopes and X rays, and fallout. The Department delegated this responsibility to the National Center for Radiological Health, Public Health Service.

Radiological Health Data and Reports, a monthly publication of the Public Health Service, includes data and reports provided to the National Center for Radiological Health by Federal agencies, State health departments, universities, and foreign governmental agencies. Pertinent original data and interpretive manuscripts are invited from investigators.

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Reports

Polonium–210 in Tobacco

Stuart C. Black and *Erich W. Bretthauer* [1]

Variations of polonium–210 content in tobacco, the amount of polonium–210 in various fractions of smoked cigarettes and changes in polonium–210 content of mainstream smoke caused by variation in the smoking procedure have been determined. The average polonium–210 content for whole cigarettes was found to be 0.483 pCi/gram and 0.477 pCi/gram for butts. No polonium–210 enrichment in the butt of cigarettes during smoking was found. Polonium–210 content and concentration in mainstream smoke increases with puff size.

The initial paper of Radford and Hunt (*1*) reporting the presence of polonium–210 in cigarettes and the possible effects of the alpha particles as a cocarcinogen for initiating lung cancer in cigarette smokers prompted many experiments which have attempted to define the problem more exactly (*2–11*). Because of the uncertainty in lung deposition, equilibrium rates, smoking procedures and dose calculations, some disagreement about the significance of polonium–210 in tobacco has arisen (*12*). An experimental program was undertaken to determine the variation of polonium–210 content in tobacco, the amount of polonium–210 in various fractions of smoked cigarettes and changes in polonium–210 content of mainstream smoke caused by variation in the smoking procedure.

Methods

All paper, butt, filter, and tobacco samples were wet ashed by the nitric- perchloric-acid procedure (*13*). After plating on silver foil, the samples were counted in an internal proportional counter operating on the alpha-particle plateau. Operating on this plateau, up to 5,000 dpm of beta radioactivity contribute no counts to the alpha-particle count of the foil. The two alpha-particle counters used in this study had background count rates of 1.8 and 1.9 counts/hour and had an efficiency of 45.9 percent as determined by counting a calibrated aged radium D–E–F source. Reagent blanks, when run through the same glassware used for samples, contributed no alpha radioactivity above background when counted up to 70 hours. Recovery of added polonium–210, carried through the entire digestion and plating procedure, was quantitative. All samples were counted long enough to obtain at least 500 total counts.

A control sample consisting of 25 pounds of tobacco was prepared for internal quality control. This sample will also be used to provide aliquots for analysis by other laboratories.

If the results are reported for cigarettes only, *e.g.*, pCi/cigarette, then a consistent weight basis is unimportant, but where comparisons are to be made between portions of a cigarette, or among cigarettes, cigars, and pipe tobacco, the weight basis becomes important. All results expressed as "per gram" are based on the weight of the tobacco after drying under reduced pressure (15 mm Hg and 43° C.).

In all experiments on smoking, a standard smoking procedure was followed using a commercial smoking machine.[2] The smoking machine is designed to take a constant puff on each of four cigarettes once each minute for collection of smoke. The volume of the puff may be varied from 10 to 65 cm^3 and the duration of the puff may be varied from less than one second to four seconds, depending on the vol-

[1] Dr. Black is project director and Mr. Bretthauer is project chemist, Southwestern Radiological Health Laboratory, Las Vegas, Nev.

[2] "American Smoker," Phipps and Bird, Inc., Richmond, Va.

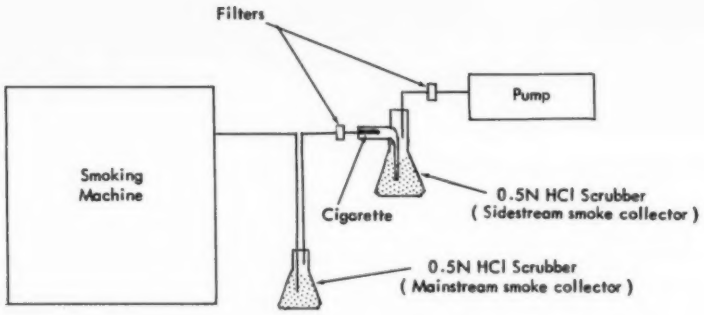

Figure 1. Apparatus for polonium–210 balance study

ume of the puff. The puff is produced by a reduction in pressure occurring when the water column in a burette is allowed to fall. The volume of the puff is controlled by regulating the rate at which water flows from the burette. The standard smoking procedure was eight puffs of two seconds duration, 36 cm^3 per puff, with a 60-second interval between puffs (*14*). This procedure was modified only in the experiments on the effect of puff size on polonium–210 in mainstream smoke. The arrangement of apparatus for collecting mainstream and sidestream smoke during balance studies is shown in figure 1. "Mainstream" means smoke taken into the mouth. "Sidestream" is smoke from the burning tip not taken into the mouth. The scrubbers, which collected smoke and polonium–210, contained 150 ml of 0.5 *N* HCl. The filters, which collected particulates and polonium–210, consisted of Whatman 541 prefilters backed by 0.45 micron Metricel filters, type GA–6.

A limited amount of data was collected to check on the puff volume of smokers. The apparatus used for this experiment is shown in figure 2. The procedure for measuring puff volume was as follows: the subject was allowed to draw several cigarette puffs with the stopper removed; the stopper was then quickly inserted just prior to a puff and the maximum height of the water column read. This procedure was repeated at least four times.

Temperature measurements were made on cigarettes during smoking by use of 0.003-inch

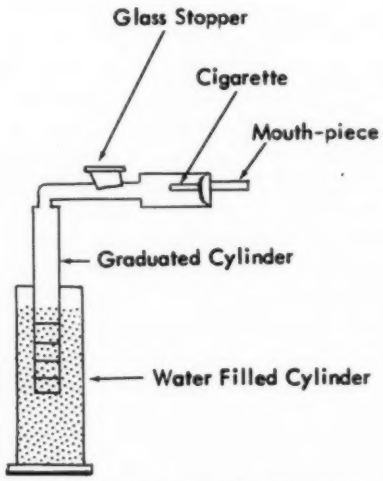

Figure 2. Puff measuring apparatus

diameter Pt–10% Rh thermocouples and a 10 mV recorder. The thermocouple was inserted in the center of the cigarette (pushed into the cigarette from the side) 20 mm behind the tip. The temperature was measured as the coal passed through the portion containing the thermocouple. The temperature of mainstream smoke was measured by placing the thermocouple immediately behind the cigarette during smoking.

Sampling for polonium–210 in the laboratory air was performed with air samplers equipped with Whatman 541 prefilters followed by 0.45 micron membrane filters. The samplers were

run for periods of 12 to 24 hours at flow rates of either 20 liters/min or 100 liters/min. These samples were taken to determine the contribution, if any, of polonium–210 to the cigarettes by the atmospheric air drawn through them during smoking.

The efficiency of commercial cigarette filters for removal of polonium–210 from mainstream smoke was determined by removing the filters from some cigarettes in a pack, smoking the cigarettes by the standard method, and measuring the polonium–210 in the mainstream smoke. Cigarettes from the same pack were analyzed, with the filters intact, by the same method for comparative purposes. The three common types of filters (cellulose, charcoal impregnated paper, and granular charcoal) were checked for filtration efficiency.

Results

The results of tobacco drying experiments indicate that a 25-hour drying time was required to attain constant weight. The samples consisted of five cigarettes each. The samples were transferred to a desiccator and allowed to cool 30 minutes before weighing.

Subsamples of the 25-pound control sample were analyzed for polonium–210 and also for homogeneity. Polonium–210 results of five random samples show an average polonium–210 content of 0.559 ± 0.010 pCi/gram of tobacco. These results indicate a high degree of homogeneity of the sample.

Two experiments were performed to determine the extent of enrichment of polonium–210, if any, in the cigarette butt. In the first experiment, a total of 12 cigarettes was smoked by the standard smoking procedure and the butts analyzed for polonium–210. In the second experiment, cigarettes were smoked and sufficient butts collected to give a total of 200 mm of length. Polonium–210 analyses on whole cigarettes were also made. The cigarettes weighed between 0.96 and 1.01 grams and the counting error was about 0.018 pCi/gram of 0.003 pCi/mm. The average polonium–210 content for whole cigarettes was 0.483 pCi/gram (0.0075 pCi/mm) and 0.477 pCi/gram (0.0076 pCi/mm) for butts. On both the unit weight and unit length bases, there was no polonium–210 enrichment in the butt of the cigarette during smoking. This conclusion was further verified by collecting sequentially puffs of smoke on separate filters. The results in table 1 show the concentration of polonium–210 in mainstream smoke to be constant, or within two standard deviations of the mean.

Table 1. Mainstream polonium–210 as a function of puff number

Filter position	Puffs collected	Number cigarettes	Average pCi/puff
1	1-3	17	[a] 0.0035±0.0002
2	4-5	17	.0037± .0002
3	6-7	17	.0044± .0002
4	8-9	[b] 11	.0042± .0002

[a] ± value is 1σ counting error.
[b] a loss of six filter papers occurred on composition.

The maximum coal temperatures during machine smoking of 10 cigarettes averaged 720° C. with a range of 664° to 812° C. The temperature of mainstream smoke is shown in figure 3 as a function of number of puffs. The smoke entering the mouth remains at constant temperature for the first six standard puffs.

The results of the balance study on smoked cigarettes are shown in table 2. The total po-

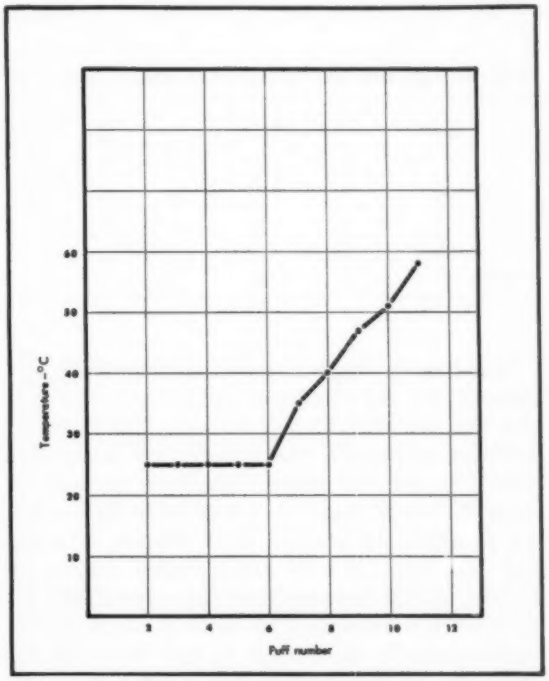

Figure 3. Mainstream smoke temperature as a function of puff number

Table 2. Balance study on artificially smoked cigarettes for polonium–210 in pCi/cigarette [a]

Number of cigarettes	Butts	Ashes	Sidestream	Mainstream	Total recovered
2	[b]0.173±0.014	0.065±0.006	0.221±0.006	0.029±0.002	0.488±0.017
2	.175± .014	.067± .007	.216± .006	.021± .002	.479± .017
2	.153± .014	.091± .008	.230± .007	.029± .002	.503± .018
2	.156± .014	.072± .006	.224± .006	.029± .002	.481± .017
Average	0.165±0.010	0.074±0.021	0.223±0.010	0.027±0.007	0.489±0.017

[a] The polonium-210 content of whole cigarettes from the same pack was 0.475±0.108 pCi/cigarette.
[b] ± value is 1σ counting error.

lonium–210 recovered from the various fractions represents quantitative recovery of the amount in unsmoked cigarettes from the same pack, within the counting error limits.

The effect of puff size on polonium–210 content in mainstream smoke is shown in figure 4. The smoking procedure was standard, only the volume of each puff being changed. The variation in puff size for humans smoking cigarettes has been reported as 27 to 61 cm³ (*15*). This range is indicated on figure 4. Data on puff size, using the apparatus shown in figure 2, were obtained from three subjects, as shown in table 3, and are in reasonable agreement with this range.

Table 3. Cigarette puff volume of laboratory personnel

Subject A (cm³)	Subject B (cm³)	Subject C (cm³)
41	39	—
38	43	68
39	46	69
39	46	71
38	45	70
Average 39	44	70

The data in figure 4 show that polonium–210 content not only increases with puff size but also the concentration increases. The routine smoking procedure was 8 puffs per cigarette, regardless of puff size. Therefore, if each of the puff sizes in figure 4 is multiplied by 8 puffs per cigarette to get the total volume inhaled, and the total pCi in mainstream smoke is divided by this volume, then the concentrations obtained are as shown in table 4. A probable explanation for this effect is that the ratio of smoke to air increases as the volume per puff increases.

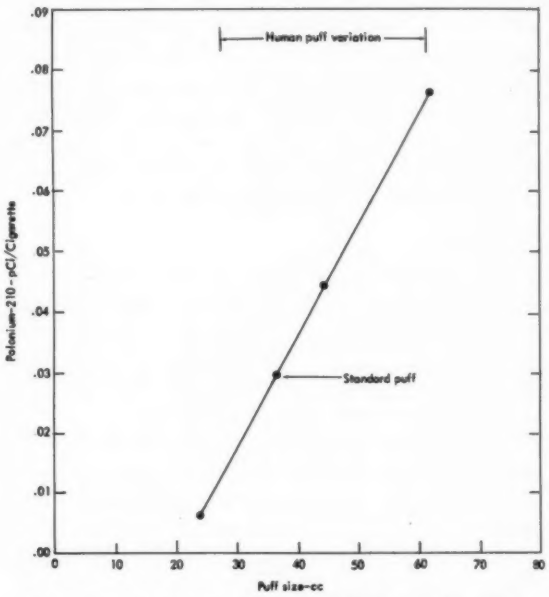

Figure 4. Variation of polonium–210 in mainstream smoke as a function of puff size

Table 4. Concentration of polonium–210 in mainstream smoke (8 puffs)

Puff size (cm³)	Inhaled volume (cm³)	Total pCi	pCi/cm³
25	200	0.0074	0.000037
36	288	.0290	.000100
44	352	.0441	.000125
62	496	.0762	.000153

The polonium–210 content of air in the laboratory is indicated by the data in table 5. The concentration ranged from 0.52 to 3.02 fCi/m³. This suggests that the volume of air used during smoking a cigarette would contribute no measurable polonium–210 to either the mainstream smoke or the butt of the cigarette.

Table 5. Polonium–210 analysis of laboratory air

Collection date (1966)	Type of collection	Volume (m^3)	Concentration (pCi/m^3)
1/5	[a]LV	21.1	2.99×10^{-3}
1/8	LV	14.4	3.02×10^{-3}
2/17	[b]HV	103.7	0.59×10^{-3}
2/18	HV	140.4	$.62 \times 10^{-3}$
2/21	HV	140.7	$.52 \times 10^{-3}$
2/23	HV	132.6	$.78 \times 10^{-3}$
2/28	HV	153.5	$.62 \times 10^{-3}$
2/28	LV	30.1	$.75 \times 10^{-3}$

[a] LV, low volume (1 cubic foot/minute).
[b] HV, high volume (12 cubic feet/minute).

The polonium–210 content in the butts and collected ashes of cigarettes smoked by machine is compared in table 6 to similar samples from cigarettes smoked by laboratory personnel. These data indicate that smoking by machine provides a reasonable duplication of the results obtained from human smoking.

Table 6. Polonium–210 content in butts and ashes after human or machine smoking

Category	Human smoker [a]		Machine smoker [a]	
	Trial 1	Trial 2	Trial 1	Trial 2
Number of cigarettes	8	6	15	15
Butt length (mm)	28–34	28–34	22–32	22–32
Butt-pCi/cigarette	0.165	0.215	0.148	0.168
Butt-pCi/gram	.469	.481	.524	.473
Ashes-pCi/cigarette (average)	0.083		0.108	
Ashes-pCi/gram (average)	.989		1.06	

[a] The same smoker (human and machine) was used for each trial.

The polonium–210 content of various brands of cigarettes, cigars, and pipe tobacco is shown in tables 7 and 8. The polonium–210 content of several foreign brands of cigarettes is shown in table 9. The cigarette papers from four brands of cigarettes (100 of each) averaged only 0.003 pCi per cigarette.

Table 7. Polonium–210 content of domestic cigarettes (non-filter type)

Brand	Number of cigarettes	Concentration (pCi/cigarette)	Concentration (pCi/gram)
A	7	0.588	[a] 0.608 ± 0.015
B	10	.544	.496 ± .014
C	10	.527	.518 ± .012
D	10	.587	.566 ± .012
E	10	.600	.568 ± .014
F	10	.585	.552 ± .015
G	10	.387	.422 ± .012
H	11	.481	.430 ± .011
Average		0.537	0.520

[a] ± value is 1σ counting error.

Table 8. Polonium–210 content of domestic tobaccos

Type	Number of brands	Number per sample	Number of replicates	Average (pCi/g)	Range (pCi/g)
Cigarettes	8	5	2	0.516	0.375–0.609
Small cigars	2	1	2	.501	.497– .503
Medium cigars	5	1	2	.563	.480– .811
Large cigars	3	1	2	.376	.284– .434
Pipe tobacco	25	[a]7	2	.399	.235– .540

[a] grams.

Table 9. Polonium–210 content of foreign cigarettes

Country	Brands analyzed	Average (pCi/cig)	Range (pCi/cig)	Average (pCi/g)	Range (pCi/g)
England	7	0.467	0.232–0.619	0.461	0.363–0.589
Canada	2	.214	.206– .222	.255	.223– .288
Egypt	1	.381		.443	
Finland	2	.291	.266– .317	.630	.469– .792
Germany	1	.518		.564	
Japan	4	.605	.454– .890	.596	.399– .801
Norway	1	.231		.218	
France	1	.626		.560	
Phillipines	1	.290		.182	
Russia	1	.382		.600	

Table 10. Efficiencies of commercial filters in removing polonium–210 from mainstream smoke

Brand	Type filter	Concentration without filters (pCi/cm^3)	Concentration with filters (pCi/cm^3)	Percent removed
XP	Cellulose	[a] 0.0301 ± 0.0017	[a] 0.0170 ± 0.0012	43
XU	Cellulose	.0290 ± .0013	.0123 ± .0008	58
XK	Cellulose	.0324 ± .0013	.0154 ± .0009	52
XH	Charcoal paper; cellulose tip	.0290 ± .0016	.0165 ± .0009	43
XL	Cellulose; granular charcoal; cellulose tip	.0262 ± .0014	.0176 ± .0010	33
XPM	Charcoal; cellulose; granular charcoal; cellulose tip	.0267 ± .0016	.0179 ± .0009	33

[a] ± value is 1 counting error.

The effect of various types of commercial cigarette filters on the concentration of polonium–210 in mainstream smoke is shown in the data of table 10.

Discussion

Any program designed to measure human exposure from smoking cigarettes must use some uniform reference method of artificially smoking the cigarettes. The standard method used in these experiments is almost identical to one proposed by the Association of Official Analytical Chemists (AOAC) (*15*) but, more importantly, it is a reproducible method and the polonium–210 analysis of various fractions of the smoked cigarette is in reasonable agreement with similar analyses on cigarettes smoked by laboratory personnel. This latter point is illustrated by the data in tables 3 and 6.

An unexpected finding is suggested by the fact that there is no apparent polonium–210 enrichment of the butt as the cigarette is smoked. We would have suspected such an enrichment, reasoning that polonium–210 volatilized by the hot coal would redeposit as the smoke cooled in moving through the remainder of the cigarette. Figure 3 indicates that the temperature of mainstream smoke is near room temperature despite the fact that it is generated at a temperature of 720° C. Some of the possible reasons for the lack of redeposit of the volatilized polonium–210 are that it was generated as an uncharged particle which readily penetrated the cigarette tobaccos, or that it was attached to very small particles that also passed through the tobacco, or that it was bound up in some organic component of the smoke which carried it through the tobacco. The cellulose filters removed about 52 percent of the polonium–210 while the charcoal filters removed only about 36 percent. This is similar to the efficiency of removal of particulate matter by each type of filter.

Domestic cigarettes are fairly uniform in polonium–210 content, the range of the average values being 0.375 to 0.609 pCi/gram. The range, for the cigars analyzed, was 0.284 to 0.811 pCi/gram and for pipe tobaccos was 0.235 to 0.540 pCi/gram. If polonium–210 content in tobaccos proves hazardous on further experimentation, then tobaccos with low polonium–210 concentrations can be analyzed to determine which constituent, *i.e.*, species of tobacco or type of treatment is responsible for the low value. This may be a desirable first step in minimizing any hazard. The wide range of polonium–210 concentrations in foreign tobaccos (table 9) suggests that there may be species or farming practices or treatment procedures which modify the polonium–210 content. Samples of cured native tobaccos from many foreign producers are being analyzed to elucidate this point. In addition, smoking styles may modify the amount of inhaled polonium–210.

Determination of the alpha-particle dosage to the lung of the smoker is, of course, one of the primary goals of this research program. Direct data which could be used to calculate a lung dosage is not available, but an estimate of the maximum possible dosage for a heavy smoker can be made, as a guide for other estimates, by using some of the results herein. A lung model is not used because two important pieces of data are missing; *i.e.*, the particle size of the polonium in tobacco smoke and the solubility of the particles. To obtain the maximum dosage, assume:

1. The average value for domestic cigarettes is 0.516 pCi/gram (table 8).
2. The mainstream smoke contains 0.076 pCi/cigarette for 62 cm^3 puffs (figure 4).
3. A subject smokes 2 packs (40 cigarettes) per day.
4. Polonium–210 is retained in bronchi until decay.
5. One hundred percent of the polonium–210 is deposited in bronchi.
6. Redistribution by ciliar movement and other processes increases concentration in certain areas by a factor of 10 ("hot spots").
7. The bronchial epithelium exposed weighs 20 grams (*16*).

Assumption 4 takes into account the pulmonary clearance classification of inorganic compounds proposed by the Task Group on Lung Dynamics for Committee II of the ICRP (*17*). It is assumed the polonium–210 as it exists in conjunction with the tobacco smoke aerosol, falls in class Y, avid retention. As-

sumption 5 reflects current thought in particle deposition; *e.g.*, the Task Group uses up to 89.6 percent deposition for 0.02 MMAD aerosols (*17*), while Jacobi calculated 80 percent total deposition for uncombined atoms (*18*). This implies that the radioactivity added per day will build up in the lung to a value equal to the radioactivity day/γ. The maximum dosage calculation is then:

$$\text{Dose} = \frac{(A)\ (B)\ (C)\ (D)\ (E)\ (F)}{(G)\ (H)\ (I)\ (J)}$$

where, for calculation of the maximum dose,

A = 0.076 pCi/cigarette (mainstream smoke concentration)
B = 40 cigarettes/day (number of cigarettes smoked)
C = 2.22 dpm/pCi (conversion factor)
D = 1440 min/day (conversion factor)
E = 5.3 MeV/disintegration (polonium–210 alpha-particle energy)
F = 1.6×10^{-6} erg/MeV (conversion factor)
G = 100 erg/gram-rad (conversion factor)
H = 0.005 days $^{-1}$ (decay constant) = λ
I = 20 grams (bronchial epithelium weight)
J = 10^{-3} rad/mrad (conversion factor)

which yields,

maximum dose = 8.25 mrad/day

The "hot spot" correction would therefore be ten times this value, or 82.5 mrad/day.

A minimum dosage estimate for a heavy smoker can be made by assuming no buildup of polonium–210 in the bronchi, deposition of 25 percent, a 36 cm^3 puff size, and a "hot spot" concentration of 2. The dose rate then becomes 3.2×10^{-5} rad/day or 0.032 mrad/day.

The range of dose rates thus calculated (0.032 to 82.5 mrad/day) can be compared to the bronchial dose rate, resulting from the short-lived radon daughters, calculated by Jacobi (*18*) or 0.39 to 0.79 mrad/day. These calculations imply that a two-pack per day cigarette smoker will add an alpha-particle dose rate to his bronchial tissue which is somewhere between 0.1 and 100 times the background dose rate. If the smoker's average dose rate is near the middle of this range and if the relative biological effectiveness for bronchogenic cancer is as high as 10, then a significant hazard may exist.

Finally, we must compare our results with those of other workers in the field, *e.g.*, the data in references (*1*), (*5*) and (*8*). The values are not directly comparable because of differences in smoking procedure. Using the data in figure 4 though, an equation can be derived to correct the data if the number of puffs and the puff size are known, *viz*:

$$\text{fCi} = (0.236X - 5.0)(Y)$$

where,

fCi = femtocuries (10^{-15} curies) in mainstream smoke,
X = puff size in cm^3, and
Y = number of puffs per cigarette.

Adjusting the data in the references by use of this formula results in good agreement among the various authors.

Conclusions

A standard smoking procedure is a necessity if results of cigarette smoking are to be compared.

For a given number of puffs per cigarette, the amount of polonium–210 and its *concentration* in mainstream smoke increases with the size of an individual puff.

Polonium–210 released by the burning tobacco is not readily removed from the smoke by either the tobacco it is moved through or, to any great extent, by cigarette filters of *various* types.

The assumptions and calculations made in this report indicate that a subject smoking two packs per day of American cigarettes receives an alpha-particle dose rate to his bronchial tissue which is somewhere between a minimum of 0.1 and a maximum of 100 times the alpha-particle dose rate delivered by the short-lived daughter products of radon at normal atmospheric levels (*18*). There are so many unknowns in this field that an attempt to use more precise figures or a given lung model would imply that we know a lot more than we do about the deposition of polonium in lung as a result of cigarette smoking.

A reduction in alpha-particle dose rate to the lung tissues can be accomplished by selecting brands with a low polonium-210 concentration if it can be demonstrated that this concentration is a stable feature of individual brands.

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SECTION I. MILK AND FOOD

In the determination of the internal exposure to man from environmental radiation sources, primary interest centers on radionuclides in the diet. Federal and State agencies are involved in efforts to monitor continuously the dietary intake of radionuclides. The most direct measure of radionuclide intake would be obtained through radioanalysis of the total diet. Difficulties in obtaining specific dietary data impede this approach. An alternate method entails the use of indicator foods to arrive at an estimate of the total dietary radionuclide intake.

Fresh milk is one such indicator food. It is consumed by a large segment of the U.S. population and contains most of the biologically significant radionuclides which appear in the diet. It also is one of the major sources of dietary intake for the short-lived radionuclides. For these reasons, fresh milk is the single food item most often used in estimating the intake of selected radionuclides by the general population and/or specific population groups. In the absence of specific dietary information, it is possible to approximate the total daily dietary intake of selected radionuclides as being equivalent to the intake represented by the consumption of 1 liter of fresh milk.

The Federal Radiation Council (FRC) has developed Radiation Protection Guides (RPG's) for controlling normal peacetime nuclear operations, assuming continuous exposure from intake by the population at large (*1–3*). The RPG's do not and cannot establish a line which is safe on one side and unsafe on the other; they do provide an indication of when there is a need to initiate careful evaluation of exposure (*3*). Additional guidelines are provided by the FRC Protective Action Guides (*4*) and by the International Commission on Radiological Protection (*5, 6*).

Data from selected national, international, and State milk and food surveillance activities are presented herein. An effort has been made to present a cross-section of routine sampling programs which may be considered of a continuing nature. Routine milk sampling has been defined as one or more samples collected per month.

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National And International Milk Surveillance

As part of continuing efforts to quantitatively monitor man's exposure to radionuclides, various national and international organizations routinely monitor radionuclide levels in milk. In addition to the programs reported, *Radiological Health Data and Reports* coverage includes:

Program	Period reported	Last presented
Radiostrontium in milk, HASL	July–December 1966	September 1967

1. Pasteurized Milk Network November 1967

National Center for Radiological Health and *National Center for Urban and Industrial Health, PHS*

The Public Health Service's Pasteurized Milk Network (PMN) is designed to provide nationwide surveillance of radionuclide concentrations in milk through sampling from major milk production and consumption areas. The present network of 63 stations (figure 1) provides data on milk in every State, the Canal Zone, Puerto Rico, and Washington, D.C. The most recent description of the sampling and analytical procedures employed by the PMN appeared in the January 1968 issue of *Radiological Health Data and Reports* (*1*). Reference should also be made to the February 1968 issue (*2*), in which changes in the interpretation and reporting of data were introduced.

Table 1. Analytical errors associated with determinations of radionuclide concentrations in a milk sample

Nuclide	Concentration (pCi/liter)	Error [a] (pCi/liter)	Concentration (pCi/liter)	Error [a] (percent of concentration)
Strontium-89	< 50	5	≥ 50	10
Strontium-90	< 20	2	≥ 20	10
Iodine-131	<100	10	≥100	10
Cesium-137	<100	10	≥100	10
Barium-140	<100	10	≥100	10

[a] Two standard deviations.

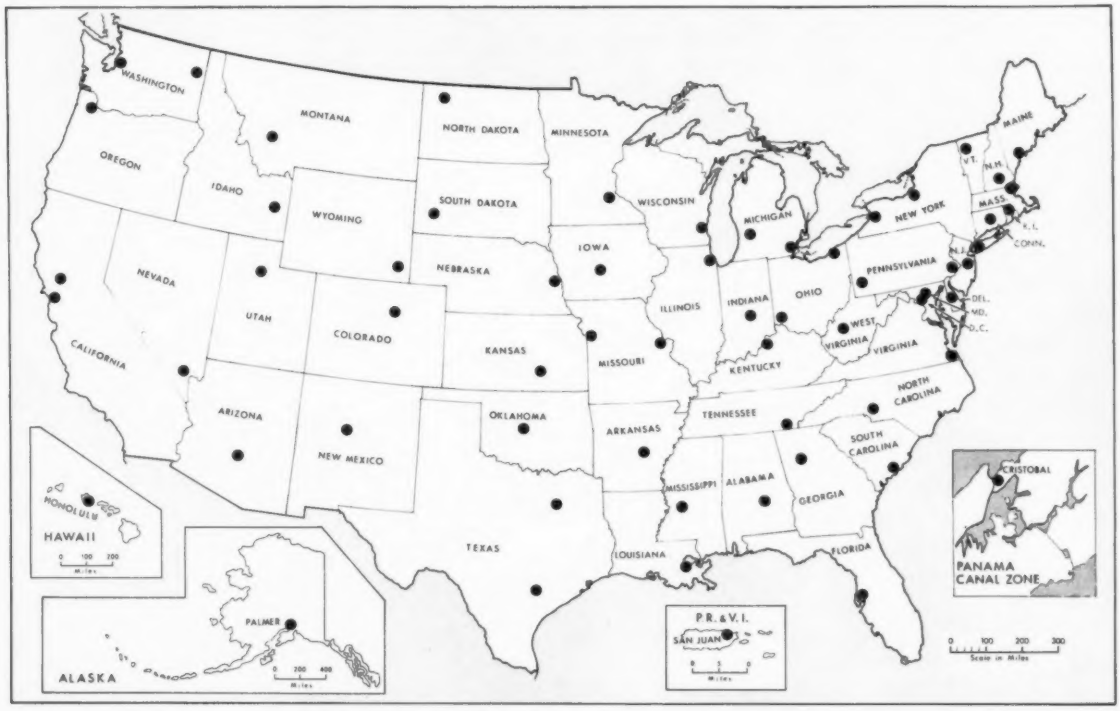

Figure 1. Pasteurized Milk Network sampling stations

Table 2. Average concentrations of radionuclides in pasteurized milk for November 1967 and the 12-month period, December 1966 through November 1967[a]

Sampling locations	Concentrations (pCi/liter)									
	Strontium-89		Strontium-90		Iodine-131		Cesium-137		Barium-140	
	Dec. 1966-Nov. 1967	November 1967[b]	Dec. 1966-Nov. 1967	November 1967	Dec. 1966-Nov. 1967	November 1967	Dec. 1966-Nov. 1967	November 1967	Dec. 1966-Nov. 1967	November 1967
Ala: Montgomery	0	0	10	8	2	0	16	12	0	0
Alaska: Palmer	0	0	8	5	0	0	21	12	0	0
Ariz: Phoenix	0	0	2	1	0	0	1	3	0	0
Ark: Little Rock	1	0	23	16	1	0	20	20	0	0
Calif: Sacramento	2	0	3	2	2	0	3	0	0	0
San Francisco	2	0	3	0	1	0	2	0	0	0
C.Z.: Cristobal	0	0	4	1	0	0	22	13	0	0
Colo: Denver	0	3	6	5	1	0	4	0	0	0
Conn: Hartford	0	--	9	7	1	0	20	17	0	0
Del: Wilmington	0	--	12	11	1	0	15	13	0	0
D.C.: Washington	0	0	10	8	0	0	10	5	0	0
Fla: Tampa	1	0	9	8	1	0	76	72	0	0
Ga: Atlanta	0	0	16	14	3	0	24	19	0	0
Hawaii: Honolulu	0	0	4	4	1	0	10	4	2	0
Idaho: Idaho Falls	1	3	7	4	0	0	8	3	0	0
Ill: Chicago	0	0	9	7	1	0	15	6	0	0
Ind: Indianapolis	0	--	9	6	0	0	11	5	0	0
Iowa: Des Moines	1	0	8	5	0	0	7	10	1	0
Kans: Wichita	1	0	9	8	0	0	5	7	0	0
Ky: Louisville	2	0	13	10	0	0	9	2	1	0
La: New Orleans	1	0	25	20	1	0	29	20	1	0
Maine: Portland	0	0	12	9	0	0	38	26	0	0
Md.: Baltimore	0	0	11	10	0	0	13	5	0	0
Mass: Boston	0	0	12	11	0	0	32	22	0	0
Mich: Detroit	0	--	9	8	1	0	16	10	0	0
Grand Rapids	0	0	10	10	0	0	19	13	0	0
Minn: Minneapolis	1	0	14	12	0	0	14	7	0	0
Miss: Jackson	2	0	19	16	2	0	17	10	0	0
Mo: Kansas City	1	0	10	6	1	0	3	0	1	0
St. Louis	2	0	10	10	0	0	7	7	1	0
Mont: Helena	1	0	7	6	0	0	10	9	0	0
Nebr: Omaha	0	0	9	7	1	0	6	3	0	0
Nev: Las Vegas	0	0	2	0	0	0	2	0	0	0
N.H.: Manchester	0	--	15	12	0	0	44	28	0	0
N.J.: Trenton	0	0	10	11	0	0	16	10	0	0
N. Mex: Albuquerque	0	3	3	0	0	0	1	0	0	0
N.Y.: Buffalo	0	--	9	3	0	0	16	10	1	0
New York City	0	0	11	8	0	0	18	15	0	0
Syracuse	0	--	9	11	1	0	18	0	0	0
N.C.: Charlotte	0	0	18	15	0	0	17	14	1	0
N. Dak: Minot	3	2	15	10	0	0	14	8	0	0
Ohio: Cincinnati	0	0	10	7	0	0	11	7	0	0
Cleveland	0	--	10	11	1	0	15	8	0	0
Okla: Oklahoma City	0	0	10	9	1	0	5	0	0	0
Ore: Portland	2	0	8	6	2	0	14	11	0	0
Pa: Philadelphia	0	--	10	8	1	0	13	9	0	0
Pittsburgh	0	--	13	10	1	0	20	14	0	0
P.R.: San Juan	2	0	5	5	0	0	15	14	0	0
R.I.: Providence	0	0	11	10	0	0	25	11	0	0
S.C.: Charleston	0	0	17	13	4	0	32	31	0	0
S. Dak: Rapid City	2	3	12	10	1	0	13	7	1	0
Tenn: Chattanooga	0	0	17	14	1	0	17	13	1	0
Memphis	0	0	13	9	1	0	5	3	0	0
Tex: Austin	0	0	4	3	3	0	4	0	0	0
Dallas	0	0	9	6	2	0	7	0	0	0
Utah: Salt Lake City	1	0	7	5	1	0	10	12	0	0
Vt: Burlington	0	0	11	10	1	0	20	13	0	0
Va: Norfolk	1	0	13	11	1	0	12	7	1	1
Wash: Seattle	2	0	11	10	0	0	28	14	0	0
Spokane	0	0	10	7	0	0	19	9	0	3
W. Va: Charleston	0	0	12	9	0	0	8	3	0	0
Wisc: Milwaukee	0	--	8	7	0	0	15	12	0	0
Wyo: Laramie	0	0	6	4	0	0	5	0	0	0
Network average	1	0	10	9	1	0	15	10	0	0

[a] See text for averaging purposes.
[b] Dashes indicate no strontium-89 determinations were made on samples from station during month.

Table 1 shows the approximate analytical errors (including counting error) associated with determinations of radionuclide concentrations in milk. These errors were determined by comparing results of a large number of replicate analyses. Table 2 contains aver-

ages for November 1967 and 12-month averages for the period, December 1966 through November 1967. The 12-month average facilitates evaluations of population exposure with respect to the guidance provided by the Federal Radiation Council. This suggests average total daily intakes averaged over periods of a year as an appropriate criterion (*3*). The average radionuclide concentrations are based on results obtained from samples collected weekly. Whenever weekly concentrations were less than or equal to the appropriate minimum detectable levels, zero was used for averaging purposes (*2*). At very low radionuclide concentrations this often results in averages lower than the minimum detectable concentration for a single sample but reflects that some of the samples making up the average were above the detectable level. The minimum detectable concentration is defined as the measured concentration equal to the two-standard deviation analytical error. Accordingly, the minimum detectable concentration in units of pCi/liter are: strontium–89, 5; strontium–90, 2; cesium–137, barium–140, and iodine–131, 10.

For comparative purposes, distributions of strontium–90 and cesium–137 are presented in tables 3 and 4 for November 1966, and June through November 1967. The average strontium–90 concentrations in pasteurized milk from selected cities are presented in figure 2.

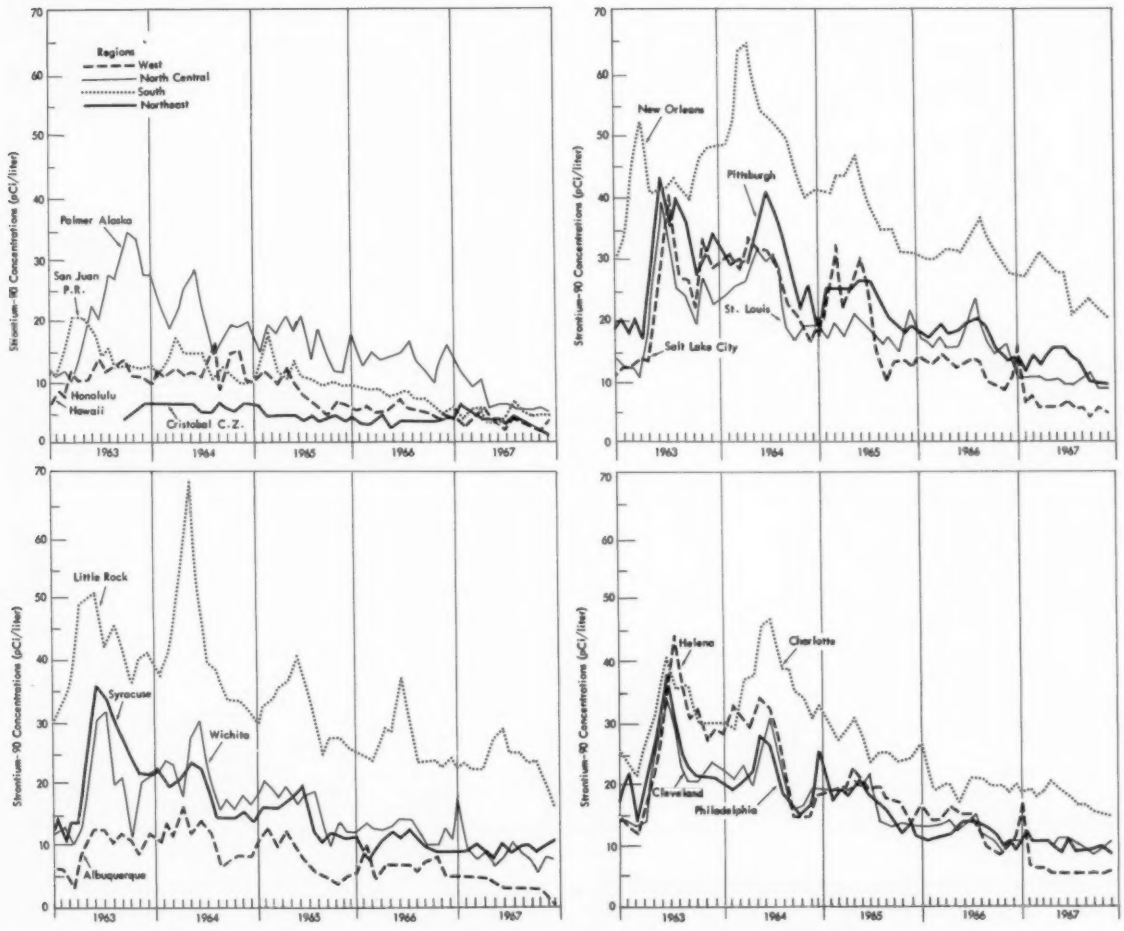

Figure 2. Strontium–90 concentrations in pasteurized milk, 1961–November 1967

Table 3. Frequently distribution, strontium–90 concentrations at PMN stations November 1966 and June–November 1967

Strontium-90 (pCi/liter)	Number of stations[a]						
	1966	1967					
	Nov	June	July	Aug	Sept	Oct	Nov
Under 10	19(30)	27(43)	25(40)	35(55)	37(59)	46(73)	43(68)
10–19	40(64)	34(54)	35(55)	26(42)	24(38)	16(25)	19(30)
20–29	4(6)	2(3)	3(5)	2(3)	2(3)	1(2)	1(2)

[a] Percentage of stations shown in parentheses.

Table 4. Frequency distribution, cesium–137 concentrations at PMN stations November 1966 and June–November 1967

Cesium-137 (pCi/liter)	Number of stations[a]						
	1966	1967					
	Nov	June	July	Aug	Sept	Oct	Nov
Under 50	61(97)	61(97)	61(97)	61(97)	62(98)	62(98)	62(98)
50–99	2(3)	2(3)	2(3)	2(3)	1(2)	1(2)	1(2)

[a] Percentage of stations shown in parentheses.

2. Canadian Milk Network November 1967 [1]

Radiation Protection Division
Department of National Health and Welfare

Since November 1955, the Radiation Protection Division of the Department of National Health and Welfare has been monitoring milk for radionuclide concentrations. Powdered milk was originally sampled, but liquid whole milk has been sampled since January 1963. At present, 16 milk sampling stations (figure 3) are in operation. Their locations coincide with air and precipitation sampling stations.

[1] Prepared from December 1967 monthly report, "Data from Radiation Protection Programs," Canadian Department of National Health and Welfare, Ottawa, Canada.

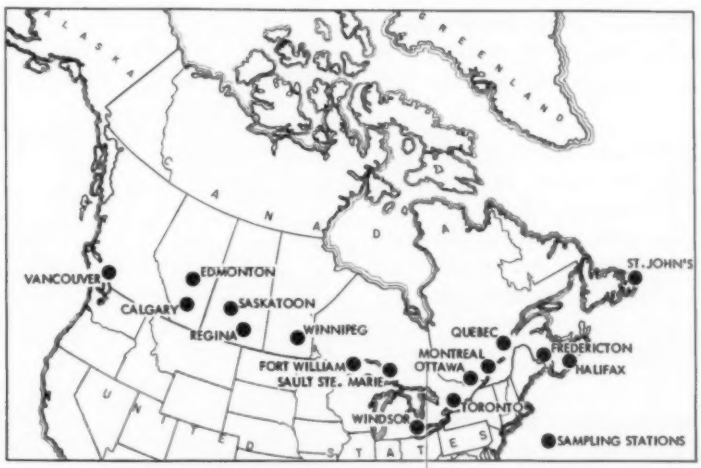

Figure 3. Canadian milk sampling stations

Milk samples are collected three times a week from selected dairies and are combined into weekly composites. The contribution of each dairy to the composite sample is directly proportional to the liquid volume of sales. Weekly spot check analyses are made for iodine–131, and monthly composites are analyzed for strontium–90, cesium–137, and stable calcium and potassium. The analytical procedures were outlined in the December 1966 issue of *Radiological Health Data and Reports* (*4*).

The November 1967 monthly average strontium–90, cesium–137, and stable calcium and potassium concentrations in Canadian whole milk are presented in table 5. Iodine–131 and strontium–89 concentrations were below minimum detectable levels.

Table 5. Stable elements and radionuclides in Canadian whole milk, November 1967

Station	Calcium (g/liter)	Potassium (g/liter)	Strontium-90 (pCi/liter)	Cesium-137 (pCi/liter)
Calgary	1.21	1.5	10	16
Edmonton	1.14	1.6	8	18
Ft. William	1.08	1.5	13	25
Fredericton	1.04	1.5	13	23
Halifax	1.16	1.5	14	21
Montreal	1.06	1.5	11	20
Ottawa	1.12	1.5	8	19
Quebec	1.09	1.5	13	28
Regina	1.13	1.5	8	18
St. John's, Nfld	1.10	1.5	17	31
Saskatoon	1.13	1.5	9	12
Sault Ste. Marie	1.07	1.6	13	29
Toronto	1.10	1.5	5	16
Vancouver	1.24	1.6	16	41
Windsor	1.18	1.5	5	13
Winnipeg	1.11	1.6	7	27
Average	1.12	1.5	11	22

3. Pan American Milk Sampling Program November 1967

Pan American Health Organization and *U.S. Public Health Service*

The Pan American Health Organization (PAHO), in collaboration with the U.S. Public Health Service (PHS), furnishes assistance to health agencies in the American republics in developing national radiological health programs.

Under a joint agreement between agencies, air and milk sampling activities are conducted by a number of PAHO member countries (figure 4). Results of the milk sampling program are presented below. Further information on the sampling and analytical procedures employed was presented in the December 1966 issue of *Radiological Health Data and Reports* (*5*).

Table 6 presents stable potassium, strontium–90 and cesium–137 monthly concentrations for November 1967.

Figure 4. Pan American Milk Sampling Program stations

Table 6. Stable element and radionuclide concentrations in PAHO milk[a], November 1967

Sampling Stations		Number of samples	Potassium (g/liter)	Strontium-90 (pCi/liter)	Cesium-137 (pCi/liter)
Chile:	Santiago	1	1.6	<1	10
Colombia:	Bogota	1	1.5	2	10
Ecuador:	Guayaquil	1	1.6	<1	10
Jamaica:	Mandeville	1	1.6	7	140
Venezuela:	Caracas	0			
Canal Zone:	Cristobal[b]	4	1.5	4	14
Puerto Rico:	San Juan[b]	4	1.6	5	13

[a] Strontium-89 was less than 5 pCi/liter and iodine-131 and barium-140 were less than 10 pCi/liter for all samples.
[b] For comparison purposes, the radionuclide concentrations at Cristobal, Canal Zone, and San Juan, Puerto Rico, from the Pasteurized Milk Network are presented.

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State Milk Surveillance Activities

Considerable progress has been made by the State health departments in initiating or expanding environmental surveillance activities in radiological health. Many of the States now have comprehensive environmental surveillance programs and self-sustaining radiological health laboratories.

The continuing efforts of State health departments in the analysis and monitoring of radionuclides in milk complement Federal milk surveillance activities. State milk surveillance activities are continually undergoing developmental changes. The results presented herein are representative of current surveillance activities directed at the use of milk as an indicator of dietary intake of radioactivity.

Figure 1 shows the States which report milk surveillance activities in *Radiological Health Data and Reports*. States having programs appearing in this issue are highlighted in the figure. Following is a summary of previously covered State programs, their reporting period, and the last issue in which they appeared.

State milk network	Period reported	Last presented
Colorado	July–September 1967	January 1968
Connecticut	July–September 1967	February 1968
Florida	July–September 1967	January 1968
Indiana	July–September 1967	February 1968
Iowa	July–September 1967	February 1968
Michigan	July–September 1967	February 1968
Minnesota	July–September 1967	February 1968
New York	April–June 1967	November 1967
Oklahoma	July–September 1967	January 1968
Pennsylvania	July–September 1967	February 1968
Tennessee	July–September 1967	January 1968
Texas	July–September 1967	January 1968

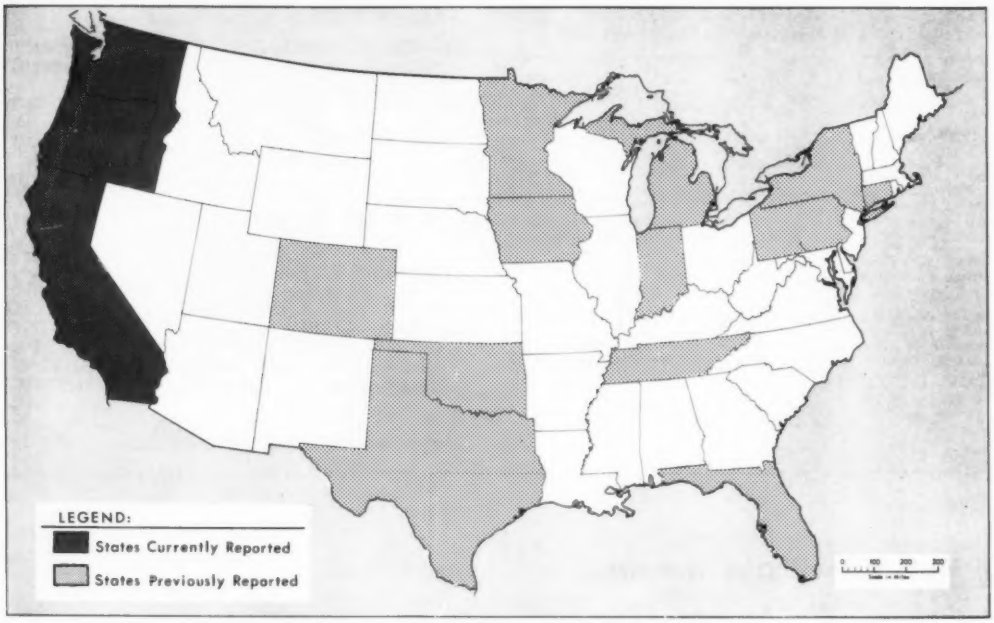

Figure 1. State milk programs reported

1. California Milk Network July–September 1967

Division of Environmental Sanitation
State of California, Department of Public Health

Surveillance of specific radionuclides in milk is one phase of the California Department of Health program on radiation control. This milk monitoring function is conducted by the Department's Bureau of Radiological Health at 10 major milksheds (figure 2).

In January 1960, the eight original sampling locations were chosen by the State Department of Agriculture so as to be representative of milk consumed by a high percentage of the State's population. The Del Norte and Mendocino milksheds were added to the program in March 1962 and since that time, weekly, biweekly or monthly sampling of pasteurized milk has been conducted in 10 milkshed areas of the State. A description of the various California milksheds was presented earlier by Heslep and Cornish (*1*).

Strontium–89 and strontium–90 concentrations are determined radiochemically. Potassium–40, iodine–131, cesium–137, and barium–140 in whole fluid milk are determined by gamma-ray scintillation spectrometry. A detailed description of the analytical procedures was presented in an earlier report (*2*).

The monthly calcium and radionuclide concentrations in California pasteurized milk are given in table 1 for the period of July to September 1967. Iodine–131 concentrations for this period were below detectable levels and are not reported in table 1.

Network average strontium–90 and cesium–137 concentrations are presented graphically in figure 3.

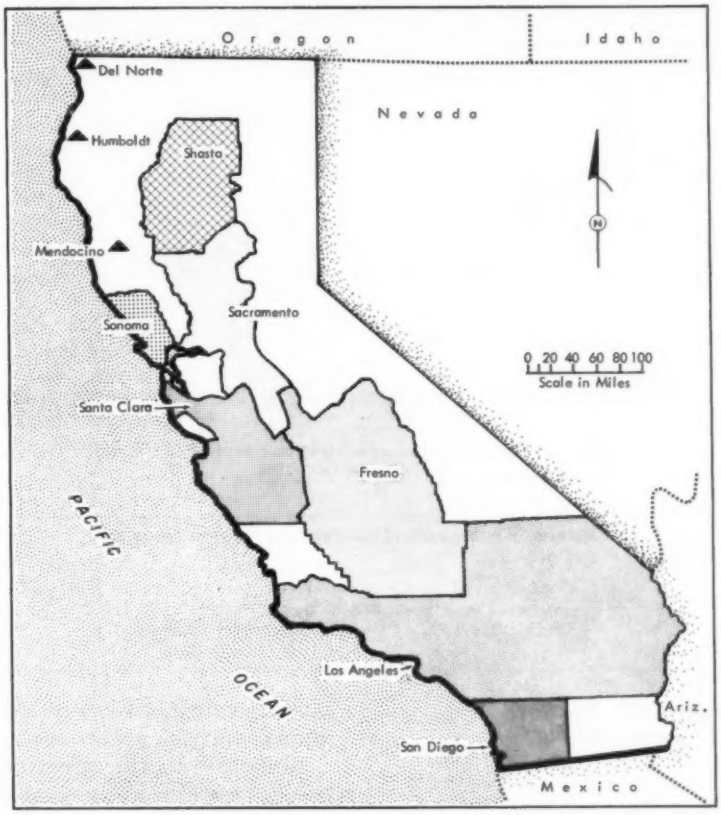

Figure 2. California milksheds

Table 1. Stable elements and radionuclides in California milk, July–September 1967

Sampling location	Calcium (g/liter)			Potassium-40 (pCi/liter)			Strontium-89 (pCi/liter)			Strontium-90 (pCi/liter)			Cesium-137 (pCi/liter)			Barium-140 (pCi/liter)		
	July	Aug	Sept	July	Aug	Sept	July	Aug	Sept	July	Aug	Sept	July	Aug	Sept	July	Aug	Sept
Del Norte	NS	NS	1.10	NS	NS	1,200	NS	NS	8	NS	NS	16	NS	NS	8	NS	NS	7
Fresno	1.10	0.95	1.24	1,230	1,350	1,240	[a]2	ND	3	[a]1	1	ND	11	[a]3	[a]7	[a]14	ND	15
Humboldt	1.33	1.29	1.17	1,110	1,090	1,120	ND	ND	ND	5	5	3	9	10	10	[a]11	26	[a]12
Los Angeles	1.11	1.05	1.08	1,280	1,310	1,350	[a]1	ND	ND	1	2	2	[a]4	ND	[a]8	15	ND	[a]9
Mendocino	1.20	1.19	1.13	1,190	1,240	1,230	[a]2	[a]1	[a]1	4	3	1	9	10	[a]3	[a]10	22	[a]6
Sacramento	1.20	1.11	1.14	1,240	1,260	1,230	3	ND	[a]1	3	2	1	[a]7	ND	9	[a]8	ND	[a]13
San Diego	1.15	1.13	1.11	1,200	1,230	NA	[a]1	ND	[a]2	1	3	ND	[a]5	ND	21	[a]8	ND	ND
Santa Clara	1.11	1.12	1.09	1,100	1,260	1,350	[a]1	ND	ND	2	2	ND	[a]7	[a]4	[a]5	ND	ND	[a]9
Shasta	1.13	1.07	1.12	1,200	1,280	1,320	[a]2	[a]1	ND	2	3	3	[a]5	13	[a]7	[a]4	ND	ND
Sonoma	1.08	1.02	1.22	1,250	1,210	1,240	[a]2	ND	ND	2	4	2	[a]7	[a]7	[a]6	[a]9	16	[a]11
Average	1.16	1.10	1.14	1,200	1,250	1,240	[b]1	[b]0	[b]2	[b]2	2	3	[b]7	[b]5	[b]9	[b]9	7	[b]8

[a] When the counting rate of the sample is not equal to at least twice the 0.95 error, the value reported is the best available estimate, but is not statistically significant.

[b] Estimate of average, if 10 percent or more of the values averaged are not statistically significant.

NA, no analysis performed.

NS, no sample collected.

ND, nondetectable.

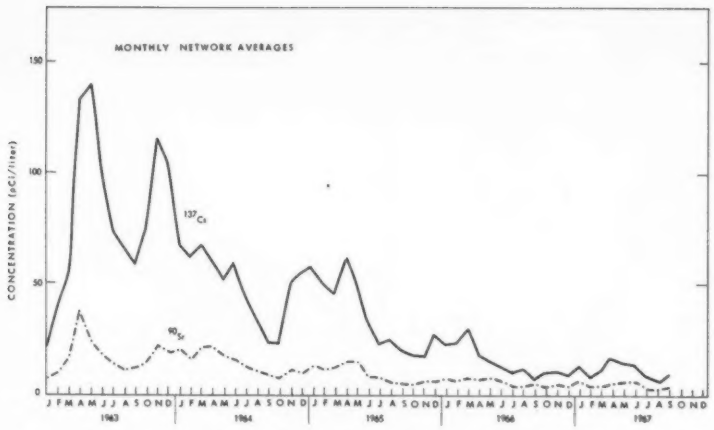
MONTHLY NETWORK AVERAGES
CONCENTRATION (pCi/liter)
150
100
50
0
^{137}Cs
^{90}Sr
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1963
1964
1965
1966
1967

Figure 3. Radionuclide concentrations in California milk 1963–September 1967

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
October–December 1966	June 1967
April–June 1967	December 1967

2. Oregon Milk Network July–September 1967

Division of Sanitation and Engineering
Oregon State Board of Health

The Oregon State Board of Health has monitored radionuclide concentrations in milk since March 1962. As part of this program routine milk samples are collected at seven major production areas (figure 4), which supply 90 percent of the milk distributed in Oregon. Currently, pasteurized milk samples are collected monthly by the Oregon Department of Agriculture, except in the Portland area where weekly samples are collected by the city of Portland. The milk sampling frequency is accelerated to a weekly basis in areas where iodine–131 concentrations exceed 100 pCi/liter, or when cesium–137 concentrations exceed 500 pCi/liter. Strontium–90 analyses are performed on a bimonthly basis, but may be done monthly when significant increases are observed.

Strontium–90 concentrations are determined using a trichloracetic acid analytical procedure (*3*). Iodine–131, cesium–137, and barium–140 concentrations are determined by gamma-ray scintillation spectrometry (*4*).

Table 2 gives the strontium–90 and cesium–137 concentrations in pasteurized milk from July through September 1967. These data are presented graphically in figure 5. Iodine–131 and barium–140 concentrations remained below minimum detectable levels of 15 pCi/liter for all samples which were collected in July through September 1967.

Table 2. Radionuclide concentrations in Oregon pasteurized milk, July–September 1967

Location	Sampling frequency	Strontium-90 (pCi/liter)			Cesium-137 (pCi/liter)		
		July	Aug	Sept	July	Aug	Sept
Baker	M	5	NS	5	<15	NS	NS
Coos Bay	M	7	NS	8	<15	NS	NS
Eugene	M	4	NS	5	<15	NS	NS
Medford	M	5	NS	5	<15	NS	NS
Portland composite	W	7	7	6	19	20	15
Portland local	W	9	NS	7	24	NS	NS
Redmond	M	6	NS	6	<15	NS	NS
Tillamook	M	23	NS	11	50	NS	NS
Average	------	8	7	7	16	20	15

Key to symbols: M, sampled monthly.
W, sampled weekly.
NS, no sample.

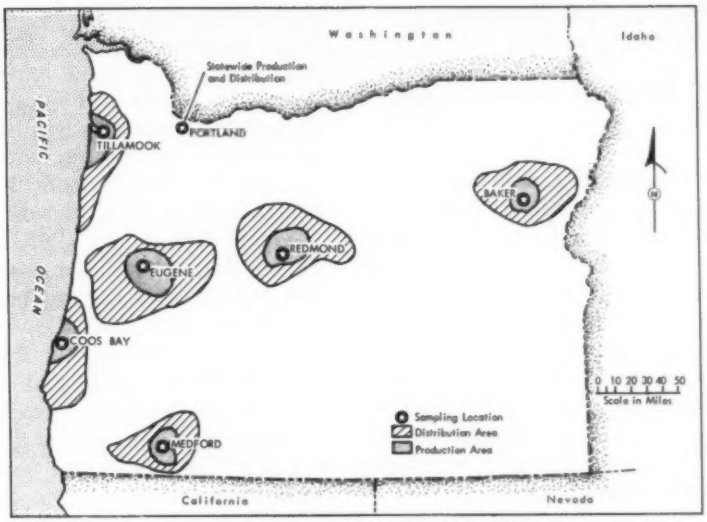

Figure 4. Oregon milk production and distribution areas

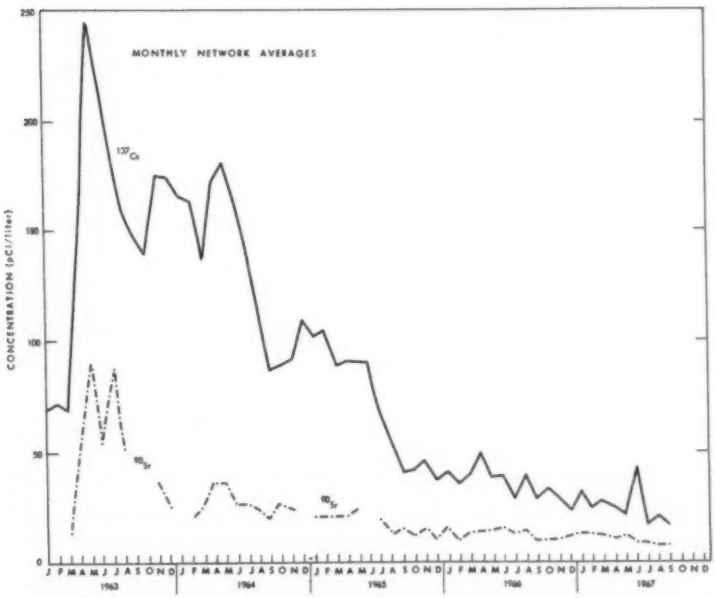
MONTHLY NETWORK AVERAGES
CONCENTRATION (pCi/liter)
250
200
150
100
50
0
^{137}Cs
^{90}Sr
^{90}Sr
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1963
1964
1965
1966
1967

Figure 5. Radionuclide concentrations in Oregon milk network 1963–September 1967

Recent coverage in *Radiological Health Data and Reports*:

Period	*Issue*
January–March 1967	September 1967
April–June 1967	December 1967

3. Washington Milk Network July–September 1967

Air Quality and Radiation Control Section
State of Washington Department of Health

The Washington State Department of Health initiated a surveillance program for radioactivity in raw milk in December 1962. The collection points shown in figure 6 were selected to provide samples representative of varying climatological conditions within the State's two major milksheds. In addition to the eight milk sampling locations in Washington, milk is sampled from Northwest Idaho (Sandpoint), as this area forms a part of the Spokane milkshed. Details of the sampling procedures were presented in an earlier report (*5*).

Selected samples are radiochemically analyzed for strontium–90. Potassium–40, iodine–131, cesium–137, and barium–140 concentrations are determined by gamma-ray scintillation spectrometry. Details of the analytical procedures were presented earlier (*5*).

Table 3 presents monthly radionuclide concentrations in Washington raw milk for July through September 1967. Samples collected during July through September 1967 contained less than 10 pCi/liter of iodine–131. Barium–140 results remained below 15 pCi/liter for all samples collected during this period. Monthly average strontium–90 and cesium–137 concentrations are presented graphically in figure 7 to display general trends.

During this reporting period, three samples were collected (one from Benton County and

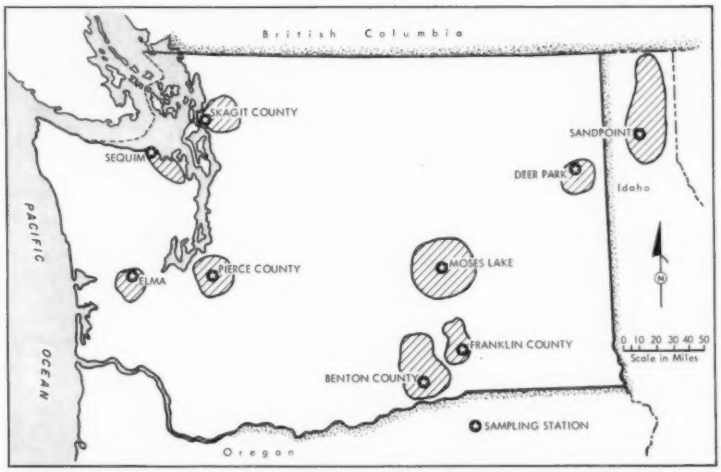

Figure 6. Washington milksheds and sampling locations

Table 3. Radionuclide concentrations in Washington raw milk, July–September 1967

Sampling location	Radionuclide concentrations (pCi/liter)								
	Potassium-40			Strontium-90			Cesium-137		
	July	Aug	Sept	July	Aug	Sept	July	Aug	Sept
Benton County	1,180	NS	1,130	4	NS	2	<15	NS	<15
Deer Park	1,160	1,110	1,190	7	7	3	<15	<15	<15
Elma	1,240	1,230	1,200	8	5	8	27	21	54
Franklin County	NS	1,180	NS	NS	3	NS	NS	<15	NS
Moses Lake	1,290	1,270	1,210	5	4	2	<15	<15	<15
Pierce County	1,110	1,180	1,270	9	6	6	18	<15	17
Sandpoint	1,200	1,270	1,220	13	16	5	28	44	40
Sequim	1,100	1,210	1,210	6	5	3	<15	<15	<15
Skagit County	1,230	1,160	1,260	16	12	7	15	37	23
Average	1,190	1,200	1,210	8	7	5	18	22	24

NS, no sample collected.

two from Franklin County) and analyzed for zinc–65. In all three cases, zinc–65 levels were less than 25 pCi/liter. Milk samples produced in areas using Columbia River water for irrigation have periodically been found to contain this radionuclide.

Recent coverage in *Radiological Health Data and Reports*:

Period	Issue
January–March 1967	September 1967
April–June 1967	December 1967

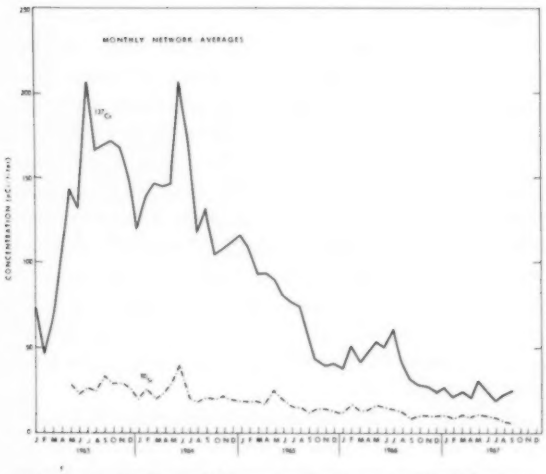

Figure 7. Radionuclide concentrations in Washington milk, 1963–September 1967

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(*2*) STATE OF CALIFORNIA DEPARTMENT OF PUBLIC HEALTH. California milk network, 1960–June 1962. Radiol Health Data 4:90–92 (February 1963).

(*3*) MURTHY, G. K., J. E. COAKLEY, and J. E. CAMPBELL. A method for the elimination of ashing in strontium–90 determinations in milk. J Diary Sci 43:151–154 (1960).

(*4*) OREGON STATE BOARD OF HEALTH, DIVISION OF SANITATION AND ENGINEERING. Oregon milk network, April–June 1965. Radiol Health Data 6:683–684 (December 1965).

(*5*) STATE OF WASHINGTON DEPARTMENT OF HEALTH, AIR AND RADIATION CONTROL SECTION. Washington milk network, January–June 1965. Radiol Health Data 6:619–621 (November 1965).

Food and Diet Surveillance

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuing basis. These estimates along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and reported routinely include those listed below. These networks provide data useful for developing estimates of nationwide dietary intakes of radionuclides. Periodically, results from the United Kingdom Diet Survey, conducted by the United Kingdom Agricultural Research Council Radiobiological Laboratory, are presented for comparison with data observed in the United States. Programs most recently reported in *Radiological Health Data and Reports* and not covered in this issue are as follows:

Program	Period reported	Last presented
California Diet Study	March–June 1967	February 1968
Connecticut Standard Diet	January–June 1967	November 1967
Institutional Diet, PHS	April–June 1967	January 1968

1. Strontium–90 in Tri-City Diets January–March 1967 [1]

Health and Safety Laboratory
U.S. Atomic Energy Commission

Since March 1960, the Health and Safety Laboratory, through its quarterly diet study, has made estimates of the strontium–90 content of the average diet of individuals living in New York City, Chicago and San Francisco.

Selected foods representing 19 food categories are purchased at each of these 3 cities every 3 months on a staggered basis (*i.e.*, Chicago, January 1967, New York City, February 1967; and San Francisco, March 1967) and are analyzed for strontium–90. Consumption figures used are based upon data from the Department of Agriculture (*1*). Some food types are assumed to be representative of larger food categories, such as liquid milk for dairy products in general.

The consumption data are based on a weight-as-purchased basis. Before the food samples for the Tri-City Diet Study are ashed for radiochemical analysis, they are prepared to a certain degree as if for actual consumption. For example, fruits are peeled, eggs are shelled, and poultry is boned. Therefore, concentrations of radioactivity in foods as reported in the Tri-City Diet Study are based on the trimmed weight. No correction is made for the waste.

After two samplings at each city, it was found that the calcium content of most food categories did not vary among cities, nor did it vary significantly with time. Calcium analyses of dietary components were performed for the third time recently, and further confirmed this result (*2*). Calcium analyses were therefore discontinued and the average calcium content of foods was computed and used to estimate the average annual intake of this material. Details of the sampling system and a discussion of the results obtained have been summarized (*3*).

Results of the January to March 1967 samplings are presented in table 1. The variation with time of the daily intake of strontium–90

[1] Data from Fallout Program Quarterly Summary Report, HASL–184. Available from the Clearinghouse for Federal Scientific & Technical Information, CFSTI, 5285 Port Royal Road, Springfield, Va. 22151.

Table 1. Average dietary consumption and strontium–90 intake in Tri-City diet January–March 1967

Food category	Diet (kg/yr)	Calcium (g/yr)	Chicago-January 1967		New York-February 1967		San Francisco-March 1967	
			(pCi/kg)	(pCi/yr)	(pCi/kg)	(pCi/yr)	(pCi/kg)	(pCi/yr)
Milk	221	234.5	6.0	1,326	10.4	2,298	3.5	774
Fresh fruit	68	12.9	7.0	476	14.6	993	7.9	537
Fresh vegetables	43	15.3	17.7	761	9.6	413	4.0	172
Root vegetables	17	6.3	10.4	177	9.3	158	6.9	117
Potatoes	45	4.9	13.6	612	0.9	41	2.3	104
Macaroni	3	0.6	7.4	22	7.4	22	4.6	14
Rice	3	1.0	1.7	5	3.5	11	1.9	6
Fruit juices	19	1.7	4.1	78	7.1	135	5.6	106
Canned vegetables	20	4.2	11.0	220	16.3	326	6.0	120
Canned fruit	26	1.3	2.6	68	3.3	86	1.1	29
Dried beans	3	3.1	21.1	63	16.2	49	1.2	4
Flour	43	8.6	12.4	533	12.0	516	2.9	125
Bakery products	37	39.2	9.4	348	5.3	196	4.9	181
Whole grain products	11	10.1	39.6	436	11.0	121	17.4	191
Fresh fish	8	8.4	4.3	34	0.6	5	0.4	3
Shell fish	1	1.2	0.3	0	1.8	2	1.7	2
Poultry	17	8.2	1.3	22	1.4	24	3.4	58
Meat	73	11.7	0.7	51	1.3	95	1.3	95
Eggs	16	9.3	2.9	46	7.1	114	1.4	22
Annual intake (pCi/yr)		382.5		5,278		5,605		2,660
Daily intake (pCi/day)		1.1		14.4		15.4		7.3
pCi strontium-90/g Ca				14		15		7

in the three cities is plotted in figure 1. A discussion of cesium–137 intakes as reflected in the Tri-City Diet Study has been presented previously (*4*).

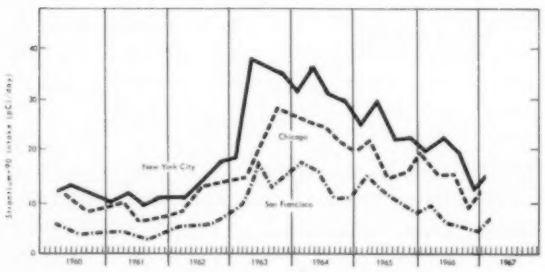

Figure 1. Daily intake of strontium–90 in Tri-City diet, March 1960–March 1967

Recent coverage in *Radiological Health Data and Reports*:

Period	Issue
February–April 1966	December 1966
May–July 1966	June 1967
August–December 1966	September 1967

REFERENCES

(*1*) U.S. DEPARTMENT OF AGRICULTURE. Food consumption of households in the United States, household food consumption survey, Report No. 1 (1955). Superintendent of Documents, Government Printing Office, Washington, D.C. 20402 (December 1956).

(*2*) U.S. ATOMIC ENERGY COMMISSION. Fallout program quarterly summary report HASL–144:281–287. Office of Technical Services, Department of Commerce, Washington, D.C. 20230 (April 1, 1964); summarized in Radiol Health Data 5:285–288 (June 1964).

(*3*) RIVERA, J., and J. H. HARLEY. HASL contributions to the study of fallout in food chains, HASL–147. Office of Technical Services, Department of Commerce, Washington, D.C. 20230 (July 1, 1964).

(*4*) U.S. ATOMIC ENERGY COMMISSION. Cesium–137 in Tri-City diets, 1965. Radiol Health Data Rep 8:154–157 (March 1967).

SECTION II. WATER

The Public Health Service, the Federal Water Pollution Control Administration and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (*1*). These standards, based on consideration of Federal Radiation Council (FRC) recommendations (*2–4*), set the limits for approval of a drinking water supply containing radium–226 and strontium–90 as 3 pCi/liter and 10 pCi/liter, respectively. Limits may be set higher if the total intake of radioactivity from all sources remains within the guides recommended by FRC for control action. In the known absence [1] of strontium–90 and alpha-particle emitters, the limit is 1,000 pCi/liter gross beta radioactivity, except when additional analysis indicates that concentrations of radionuclides are not likely to cause exposures greater than the limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water sampling activities recently reported in *Radiological Health Data and Reports* are listed below.

[1] Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha-particle emitters and strontium–90, respectively.

Activity	Period reported	Last presented
California Water Sampling Program	July–December 1966	February 1968
Coast Guard Water Sampling Program	January–December 1966	November 1967
Minnesota Municipal Water	January–June 1967	January 1968
New York Surface Water	January–May 1967	January 1968
Radiostrontium in Tap Water, HASL	July–December 1966	November 1967
Washington Surface Water Sampling	July 1965–June 1966	August 1967

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(*2*) FEDERAL RADIATION COUNCIL. Radiation Protection Guidance for Federal Agencies. Memorandum for the President, September 1961. Reprint from the Federal Register of September 26, 1961.

(*3*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1960).

(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

Gross Radioactivity in Surface Waters of the United States, September 1967

Division of Pollution Surveillance, Federal Water Pollution Control Administration
Department of Interior

The monitoring of levels of radioactivity in surface waters of the United States was begun in 1957 as part of the Federal Water Pollution Control Administration's Water Pollution Surveillance System. Table 1 presents the current preliminary results of the alpha and beta radioanalyses. The radioactivity associated with dissolved solids provides a rough indication of the levels which would occur in treated water, since nearly all suspended matter is removed by treatment processes. Strontium–90 results are reported semiannually. The stations on each river are arranged in the table according to their distance from the headwaters. Figure 1 indicates the average total beta radioactivity in suspended-plus dissolved solids in raw water collected at each station. A description of the sampling and analytical procedures was published in the August 1967 issue of *Radiological Health Data and Reports.*

Complete data and exact sampling locations for 1958 through 1963 are published in annual compilations (*1–6*). Data for subsequent years are available on request.

Special note is taken when the alpha radioactivity concentration is 15 pCi/liter or greater or when the beta radioactivity concentration is 150 pCi/liter or greater. These arbitrary levels provide a basis for the selection of certain data for comment. They reflect no public health significance as the Public Health Service drinking water standards have already pro-

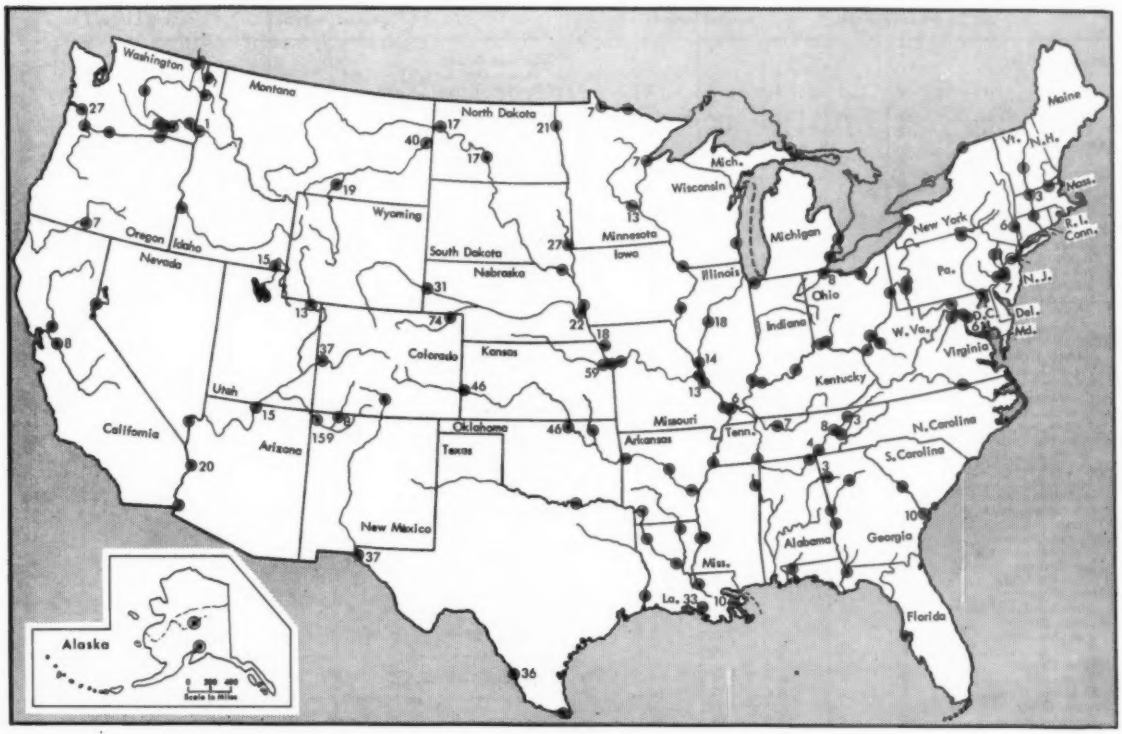

Figure 1. Sampling locations and associated total beta radioactivity (pCi/liter) in surface waters, September 1967

vided the basis for this assessment. Changes from or toward these arbitrary levels are also noted in terms of changes in radioactivity per unit weight of solids. A discussion of gross radioactivity per gram of solids for all stations of the Water Pollution Surveillance System for 1961 through 1965 has been presented (*7*). Comments are made only on monthly average values. Occasional high values from single weekly samples may be absorbed into a relatively low average. When these values are significantly high, comment will be made.

During August and September, the following stations showed values in excess of 15 pCi/liter on alpha radioactivity for either suspended or dissolved solids:

Arkansas River; Coolidge, Kans.

San Juan River; Shiprock, N. Mex.

South Platte River; Julesburg, Colo.

During September, the following stations showed values in excess of 15 pCi/liter on alpha radioactivity for either suspended or dissolved solids:

Arkansas River; Ponca City, Okla.

Kansas River; DeSoto, Kans.

North Platte River; Henry, Nebr.

Rio Grande; Laredo, Tex.

Yellowstone River; Sidney, Mont.

Table 1. Radioactivity in raw surface waters, September 1967

Station	Average alpha radioactivity (pCi/liter)			Average beta radioactivity (pCi/liter)		
	Suspended	Dissolved	Total	Suspended	Dissolved	Total
Animas River: Cedar Hill, N. Mex.	1	3	4	2	6	8
Arkansas River: Coolidge, Kans.	10	21	31	26	20	46
Ponca City, Okla.	17	7	24	36	10	46
Atchafalaya River: Morgan City, La.	8	1	9	25	8	33
Bear River: Preston, Idaho	0	1	1	0	15	15
Big Horn River: Hardin, Mont.	4	3	7	8	11	19
Big Sioux River: Sioux Falls, S. Dak.	2	6	8	4	23	27
Clearwater River: Lewiston, Idaho	0	0	0	0	1	1
Clinch River: Clinton, Tenn.	2	2	4	0	3	3
Kingston, Tenn.[a]	0	<1	<1	0	8	8
Colorado River: Loma, Colo.	4	7	11	21	16	37
Page, Ariz.	1	10	11	<1	15	15
Parker Dam, Calif.-Ariz.	0	5	5	0	20	20
Columbia River: Clatskanie, Ore.	0	0	0	3	24	27
Connecticut River: Northfield, Mass.	0	0	0	0	3	3
Coosa River: Rome, Ga.	1	1	2	1	2	3
Cumberland River: Cheatham Lock, Tenn.	1	1	2	4	3	7
Delaware River: Philadelphia, Pa.	1	2	3	1	6	7
Great Lakes: Duluth, Minn.	1	1	2	4	3	7
Green River: Dutch John, Utah	<1	5	5	0	13	13
Hudson River: Poughkeepsie, N. Y.	2	2	4	0	6	6
Illinois River: Peoria, Ill.	2	6	8	4	14	18
Grafton, Ill.	1	7	8	2	12	14
Kansas River: DeSoto, Kans.	35	6	41	44	15	59
Klamath River: Keno, Ore.	<1	1	1	<1	7	7
Maumee River: Toledo, Ohio	1	1	2	1	7	8
Mississippi River: St. Paul, Minn.	1	3	4	1	12	13
E. St. Louis, Ill.	1	5	6	1	12	13
New Orleans, La.	0	1	1	0	10	10
Missouri River: Williston, N. Dak.	1	1	2	5	12	17
Bismarck, N. Dak.	3	8	11	4	13	17
St. Joseph, Mo.	1	3	4	4	14	18
North Platte River: Henry, Nebr.	1	19	20	3	28	31
Ohio River: Cairo, Ill.	2	3	5	1	5	6
Platte River: Plattsmouth, Nebr.	4	5	9	9	13	22
Potomac River: Washington, D.C.	1	2	3	1	5	6
Rainy River: Baudette, Minn.	<1	1	1	0	7	7
Red River, North: Grand Forks, N. Dak.	0	1	1	2	19	21
Rio Grande: El Paso, Tex.	13	11	24	22	15	37
Laredo, Tex.	16	4	20	28	8	36
San Joaquin River: Vernalis, Calif.	0	1	1	1	7	8
San Juan River: Shiprock, N. Mex.	90	7	97	146	13	159
Savannah River: Port Wentworth, Ga.[a]	1	1	2	2	8	10
South Platte River: Julesburg, Colo.	3	48	51	7	67	74
Tennessee River: Chattanooga, Tenn.	1	1	2	1	3	4
Yellowstone River: Sidney, Mont.	19	7	26	32	8	40
Maximum	90	48	97	146	67	159
Minimum	0	0	0	0	1	1

[a] Gross beta radioactivity at this station may not be directly comparable to gross beta radioactivity at other stations because of the possible contribution of radionuclides from an upstream nuclear facility in addition to the contribution from fallout and naturally occurring radionuclides.

Cedar Hill, N. Mex., on the Animas River decreased to less than 15 pCi/liter on alpha radioactivity concentrations for suspended solids.

In September no station reported a beta radioactivity concentration of more than 150 pCi/liter in either suspended or dissolved solids.

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(2) *Ibid.*, 1959 Edition.
(3) *Ibid.*, 1960 Edition.
(4) *Ibid.*, 1961 Edition.
(5) *Ibid.*, 1962 Edition.
(6) PUBLIC HEALTH SERVICE, DIVISION OF WATER SUPPLY AND POLLUTION CONTROL. Water pollution surveillance system, annual compilation of data, PHS Publication No. 663 (Revised), 1963 Edition. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.
(7) JULIAN, E. C. Gross radioactivity of the solids in selected surface waters of the United States, 1961–1965. Radiol Health Data Rep 9:1–12 (January 1968).

SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product radioactivity. To date, this surveillance has been confined chiefly to gross beta radio analysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the U.S. Public Health Service, the Canadian Department of National Health and Welfare, the Mexican Commission of Nuclear Energy, and the Pan American Health Organization.

An intercomparison of the above networks was performed by Lockhart and Patterson in 1962 and is summarized in the January 1964 issue of *Radiological Health Data*. In addition to those programs presented in this issue, the following programs were previously covered in *Radiological Health Data and Reports*:

Network	Period	Issue
HASL 80th Meridian Network	Calendar year 1965	January 1967
Plutonium in Airborne Particulates	April–June 1967	November 1967

1. Radiation Alert Network[1] November 1967

National Center for Radiological Health
U.S. Public Health Service

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Alert Network (RAN) which regularly samples airborne particulates at 73 locations distributed throughout the country (figure 1). Most of the stations are operated by State health department personnel.

Airborne particulate samples are collected by drawing air through 4-inch diameter MSA No. 2133 "All-Dust" filters at high velocity using either a Staplex "Hi-Volume" sampler or one of several lobar-type positive displacement air pumps. Samples are normally collected on a daily basis for 5 days per week. The sample removed on the morning of the first day of the week usually represents a 48–96 hour sampling period for the previous weekend. Some stations equipped with the "Hi-Volume" sampler use a timing device on weekends that will repetitively turn the sampler on for 1 hour and off for 2 hours, and thus sample for 24 hours over a 72-hour period. In certain circumstances, stations are requested to operate on a daily basis.

At the completion of the sampling period, the filter is removed from the sampler and set aside for approximately 5 hours to permit decay of most of the radon daughter radioactivity that may have been collected. A field estimate of the gross beta radioactivity content is then made using a survey meter equipped with a GM probe. By comparing the result obtained from the filter with that obtained from a strontium-yttrium–90 standard of known radioactivity, the field estimate is calculated as follows:

$$\frac{\text{Net sample reading (cpm)}}{\text{Net standard reading (cpm)}} \times \frac{\text{standard radioactivity (pCi)}}{\text{sample volume (m}^3\text{)}} = \text{field estimate (pCi/m}^3\text{)}$$

[1] The name of the Radiation Surveillance Network (RSN) was changed to Radiation Alert Network (RAN) effective November 1, 1967.

Figure 1. Radiation Alert Network sampling stations

A second field estimate of the radioactivity concentration is made approximately 24 hours after the first estimate (29 hours after sample collection) at which time most of the thoron-daughter radioactivity will have decayed.

Continuous sampling of precipitation is done concurrently with air sampling at most RAN stations using funnels with a collection area of 0.4 square meters. The collected liquid, or an aliquot thereof, is evaporated to dryness and a field estimate is made of the gross beta radioactivity deposition in essentially the same manner as for an air sample. The gross beta radioactivity deposition field estimate is calculated as follows:

1. $$\frac{\text{Net sample reading (cpm)}}{\text{Net standard reading (cpm)}} \times \frac{\text{standard radioactivity (pCi)}}{\text{aliquot volume (ml)}} = \text{concentration (pCi/ml or nCi/liter)}$$

2. $$\frac{\text{Total volume of precipitation collected (liters)}}{\text{Collector area (m}^2\text{)}} = \text{depth of precipitation (mm)}$$

3. Concentration (nCi/liter) × depth of precipitation (mm) = deposition (nCi/m²)

Table 1. Gross beta radioactivity in surface air and precipitation, November 1967

Station location		Number of samples		Air surveillance gross beta radioactivity (pCi/m³)			Last profile in *RHD&R*	Precipitation	
		Air	Pptn	Maximum	Minimum	Average[a]		Total depth (mm)	Total deposition (nCi/m²)
Ala:	Montgomery	30	4	6.61	.19	2.57	Nov 67	90	[e]10
Alaska:	Adak	30	------	.36	.36	.36	June 67	------	------
	Anchorage	14	1	.00	.00	.00	Dec 67	10	0
	Attu Island	6	------	.81	.00	.14	July 67	------	------
	Fairbanks	[b]	------	------	------	------	Jan 68	------	------
	Juneau	12	9	.00	.00	.00	Feb 68	176	0
	Kodiak	20	------	.70	.00	.13	Mar 68	------	------
	Nome	30	------	.68	.21	.34	Sept 67	------	------
	Pt. Barrow	30	------	.64	.59	.61	Aug 67	------	------
	St. Paul Island	30	------	1.33	.43	.54	Oct 67	------	------
Ariz:	Phoenix	21	6	18.97	1.44	6.50	Feb 68	47	------
Ark:	Little Rock	17	3	2.25	.20	.72	Dec 67	24	0
Calif:	Berkeley	21	4	3.84	.00	1.15	Mar 68	167	0
	Los Angeles	21	------	2.21	.24	.92	Sept 67	------	------
Colo:	Denver	20	------	8.10	.13	2.83	Mar 68	------	------
Conn:	Hartford	19	9	.42	.12	.24	Jan 68	74	[e]<8
Del:	Dover	20	------	1.44	.14	.43	Nov 67	------	------
D. C:	Washington	27	5	2.20	.22	.74	Aug 67	35	<8
Fla:	Jacksonville	19	1	.99	.24	.41	Dec 67	8	<2
	Miami	18	6	.26	.06	.17	Jan 68	49	0
Ga:	Atlanta	19	7	3.43	.37	.96	Oct 67	194	[e]123
Guam:	Agana	[b]	------	------	------	------	Nov 67	------	------
Hawaii:	Honolulu	30	3	.83	.30	.43	July 67	[d]52	[d]
Idaho:	Boise	20	3	6.04	.95	2.68	July 67	19	0
Ill:	Springfield	18	5	3.81	.16	.88	Aug 67	39	------
Ind:	Indianapolis	18	9	1.39	.65	.86	Oct 67	51	[e]<41
Iowa:	Iowa City	15	2	2.92	.97	1.71	Mar 68	37	<7
Kans:	Topeka	19	3	3.44	.34	1.07	Dec 67	22	<4
Ky:	Frankfort	15	7	1.97	.69	1.14	Aug 67	52	[e]117
La:	New Orleans	20	2	1.10	.11	.38	Aug 67	[d]19	[d]
Maine:	Augusta	20	6	1.27	.09	.41	Feb 68	91	<3
Md:	Baltimore	21	4	2.38	.31	.69	Jan 68	22	[e]16
	Rockville	13	[f]1	.74	.11	.28	July 67	[d]117	[d]
Mass:	Lawrence	18	6	1.37	.00	.24	Nov 67	80	<1
	Winchester	19	9	2.75	.00	.18	June 67	64	<1
Mich:	Lansing	20	7	2.31	.14	.84	July 67	56	[e]<32
Minn:	Minneapolis	20	------	.59	.19	.26	Nov 67	------	------
Miss:	Jackson	17	1	1.86	.21	.76	Feb 68	6	<1
Mo:	Jefferson City	20	5	2.02	.18	.57	Oct 67	40	<3
Mont:	Helena	21	4	4.32	.24	1.27	June 67	10	[e]<5
Nebr:	Lincoln	20	2	4.13	.99	2.13	Oct 67	12	<2
Nev:	Las Vegas	15	------	3.47	.17	1.42	Jan 68	------	------
N. H:	Concord	19	------	1.94	.00	.47	Aug 67	------	------
N. J:	Trenton	18	3	.51	.12	.21	Feb 68	8	[e]8
N. Mex:	Santa Fe	17	1	1.96	.06	.82	June 67	3	[e]3
N. Y:	Albany	18	8	.78	.11	.48	Oct 67	70	[e]<79
	Buffalo	2	------	.32	.19	.25	Mar 68	------	------
	New York	20	------	.42	.16	.19	June 67	------	------
N. C:	Gastonia	16	3	12.73	.36	5.06	Mar 68	[d]32	[d]
N. Dak:	Bismarck	21	1	3.86	.25	1.64	Aug 67	1	------
Ohio:	Cincinnati	18	------	2.81	.40	1.17	Nov 67	------	------
	Columbus	17	2	1.33	.14	.45	Feb 68	17	0
	Painesville	21	8	1.87	.11	.46	Jan 68	115	[e]<18

See footnotes at end of table.

Table 1. Gross beta radioactivity in surface air and precipitation, November 1967—Continued

Station location		Number of samples		Air surveillance gross beta radioactivity (pCi/m³)			Last profile in *RHD&R*	Precipitation	
		Air	Pptn	Maximum	Minimum	Average[a]		Total depth (mm)	Total deposition (nCi/m²)
Okla:	Oklahoma City	18		6.09	.00	1.12	July 67		
	Ponca City	21	2	7.95	.16	1.34	Jan 68	5	<1
Ore:	Portland	17	8	1.13	.00	.35	Oct 67	60	
Pa:	Harrisburg	17		1.68	.32	.77	Oct 67		
P. R:	San Juan	[b]					Feb 68		
R. I:	Providence	21	9	.55	.00	.15	July 67	64	<1
S. C:	Columbia	9	4	1.42	.00	.54	June 67	86	<2
S. Dak:	Pierre	10		8.52	1.21	3.52	Feb 68		
Tenn:	Nashville	11	6	1.30	.30	.70	July 67	67	0
Tex:	Austin	18	2	7.27	.18	2.08	Nov 67	[d]61	[d]
	El Paso	27	2	9.64	1.01	2.79	Aug 67	8	0
Utah:	Salt Lake City	30	1	1.65	.25	.92	Sept 67	11	
Vt:	Barre	21	9	1.64	.12	.43	Dec 67	34	<2
Va:	Richmond	14	4	.99	.41	.76	Dec 67	33	<3
Wash:	Seattle	[b]	12				Dec 67	[d]45	[d]
	Spokane	20	1	3.24	.44	1.03	Nov 67	7	
W. Va:	Charleston	19	12	1.76	.22	.72	June 67	108	[e]<84
Wis:	Madison	19	4	1.74	.14	.56	Dec 67	49	[e]<10
Wyo:	Cheyenne	21	2	4.20	.35	1.49	Jan 68	5	[e]3
Network summary		1,303	55	18.97	0.00	1.00		49	[e]<12

[a] The monthly average is calculated by weighting the field estimates of individual air samples with length of sampling period.
[b] Indicates no report received. (Air samples submitted without field estimate data are not considered by the data program.)
[c] The "<" before deposition value indicates that the calculation used some laboratory findings below the minimum reporting level of concentration of 200 pCi/liter.
[d] This station is part of the plutonium in precipitation net. Gross beta analysis is not done.
[e] Field estimate included.
[f] Sample collected for whole month.

Certain selected stations submit "whole-catch" liquid samples to RAN headquarters where they are composited and sent to NCRH laboratories for selected isotope analysis. These stations do not make field estimates on preciptation.

The samples and field estimate data are mailed to RAN headquarters in Rockville, Md., where compilations of data are made by automatic data processing techniques. Those samples showing abnormal radioactivity levels are forwarded to a NCRH laboratory for further detailed analysis.

The alerting function of the RAN is accomplished by having station operators report unusual findings by telephone to the RAN headquarters as soon as the readings are taken. Appropriate personnel within NCRH, other Federal agencies, and State agencies are advised of any unusual findings. Alert telephone reports are made by station operators for the following conditions:

1. the first (5 hour) field estimate on an air sample exceeds 15 pCi/m³ (7.5 pCi/m³ in Alaska, Hawaii, and Puerto Rico); or
2. the second (29 hour) field estimate on an air sample exceeds 5 pCi/m³; or
3. the field estimate on a dried precipitation sample exceeds 5 nCi/m².

Table 1 presents the monthly average gross beta radioactivity concentrations in surface air particulates (first field estimate) and total gross beta radioactivity deposition by precipitation, as measured by the field estimate technique during November 1967. Time profiles of gross beta radioactivity in air for eight RAN stations are shown in figure 2.

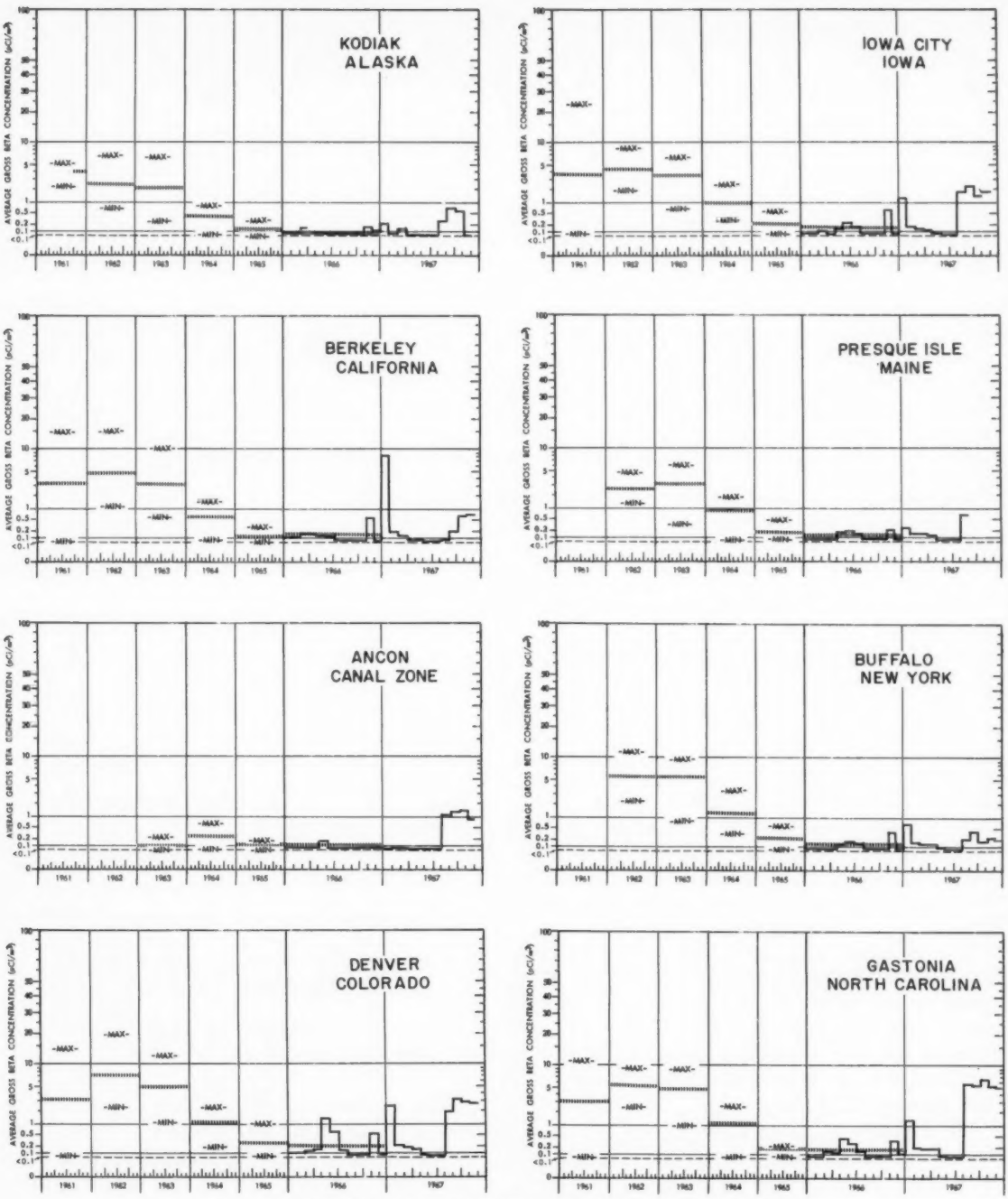

Figure 2. Monthly and yearly profiles of beta radioactivity in air—Radiation Alert Network, 1961–November 1967

2. Canadian Air and Precipitation Monitoring Program, November 1967

Radiation Protection Division
Department of National Health and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (see figure 3), where the sampling equipment is operated by personnel from the Meteorological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*1–5*).

A summary of the sampling procedures and methods of analysis was presented in the November 1966 issue of *Radiological Health Data and Reports.*

Surface air and precipitation data for November 1967 are presented in table 2.

Table 2. Canadian gross beta radioactivity in surface air and precipitation, November 1967

Station	Number of samples	Air surveillance gross beta radioactivity (pCi/m³)			Precipitation measurements	
		Maximum	Minimum	Average	Average concentrations (pCi/liter)	Total deposition (mCi/m²)
Calgary	30	0.3	0.0	0.0	NS	NS
Coral Harbour	28	.2	.0	.0	63	0.9
Edmonton	30	.2	.0	.0	32	.8
Ft. Churchill	30	.1	.0	.0	2	.1
Ft. William	30	.3	.0	.0	17	.3
Fredericton	—	—	—	—	13	1.5
Goose Bay	30	.2	.0	.0	14	.9
Halifax	30	.2	.0	.0	9	1.7
Inuvik	30	.0	.0	.0	3	.1
Montreal	30	.1	.0	.0	13	1.1
Moosonee	30	.0	.0	.0	7	.3
Ottawa	30	.4	.0	.0	11	1.0
Quebec	30	.1	.0	.0	14	1.4
Regina	28	.3	.0	.0	7	.2
Resolute	28	.1	.0	.0	NS	NS
St. John's, Nfld	30	.4	.0	.0	7	.9
Saskatoon	30	.2	.0	.0	14	.2
Saulte Ste Marie	29	.4	.0	.1	16	.9
Toronto	30	.8	.0	.0	7	.3
Vancouver	30	1.5	.0	.1	12	1.4
Whitehorse	30	.7	.0	.0	10	.2
Windsor	30	.1	.0	.0	7	.5
Winnipeg	30	.4	.0	.0	22	.3
Yellowknife	30	.0	.0	.0	13	.3
Network summary	683	1.5	0.0	0.0	14	0.7

NS, no sample.

[1] Prepared from information and data in the December 1967 monthly report "Data from Radiation Protection Program," Canadian Department of National Health and Welfare, Ottawa, Canada.

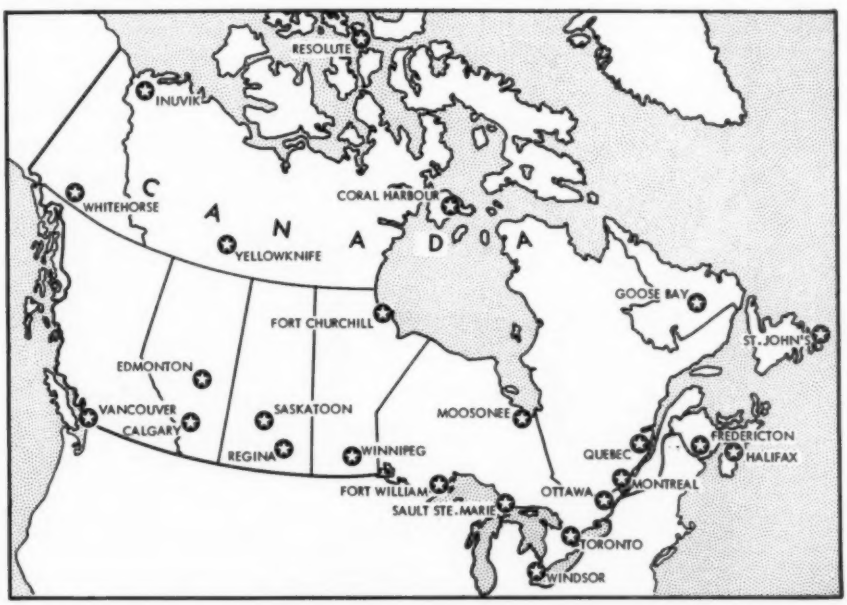

Figure 3. Canadian air and precipitation sampling stations

3. Mexican Air Monitoring Program November 1967

National Commission of Nuclear Energy

The Radiation Surveillance Network of Mexico was established by the Comisión Nacional de Energía Nuclear (CNEN), México, D. F. From 1952 to 1961, the network was directed by the Institute of Physics of the University of Mexico, under contract to the CNEN.

In 1961, the CNEN appointed its Division of Radiological Protection to establish a new Radiation Surveillance Network. In 1966, the Division of Radiological Protection was restructured and its name changed to Dirección General de Seguridad Radiológica (DRS). The network consists of 16 stations (figure 4), 11 of which are located at airports and operated by airline personnel. The remaining five stations are located at México, D. F.; Mérida; Veracruz; San Luis Potosí; and Ensenada. Staff members of the DRS operate the station at México, D. F., while the other four stations are manned by members of the Centro de Previsión del Golfo de México, the Chemistry Department of the University of Mérida, the Institute de Zonas Desérticas of the University of San Luis Potosí, and the Escuela Superior de Ciencias Marinas of the University of Baja California, respectively.

Sampling

The sampling procedure involves drawing air through a high-efficiency 6- by 9-inch glass-fiber filter for 20 hours a day, 3 or 4 days a week at the rate of 1,000 cubic meters per day using high volume samplers.

After each 20-hour sampling period, the filter is removed and shipped via airmail to the Sección de Radioactividad Ambiental, CNEN, in México, D. F., for assay of gross beta radioactivity, allowing a minimum of 3 or 4 days after collection for the decay of radon and thoron. The data are not extrapolated to the time of collection. Statistically, it has been found that a minimum of five samples per month were needed to get a reliable average radioactivity at each station (*6*).

The maximum, minimum, and average beta radioactivity in surface air during November 1967 are presented in table 3.

Figure 4. Mexican air sampling stations

Table 3. Mexican gross beta radioactivity of airborne particulates November 1967

Station	Number of samples	Gross beta radioactivity (pCi/m³)		
		Maximum	Minimum	Average
Acapulco	16	0.3	0.1	0.1
Chihuahua	12	.4	.1	.2
Ciudad Juárez	15	.3	.1	.1
Ensenada	3	.1	.1	.1
Guadalajara	NS			
Guaymas	NS			
La Paz	NS			
Matamoros	NS			
Mazatlan	13	.2	.1	.1
Merida	14	.3	.1	.1
México, D.F.	11	.3	.1	.1
Nuevo Laredo	NS			
San Luis Potosí	NS			
Tampico	13	.1	.1	.1
Torreón	NS			
Veracruz	13	.5	.1	.2

NS, station temporarily shutdown.

4. Pan American Air Sampling Program November 1967

Pan American Health Organization and *U.S. Public Health Service*

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the U.S. Public Health Service (PHS) to assist PAHO-member countries in developing radiological health programs.

Beginning with the present reporting period, sampling equipment and analytical services are being provided by the Southeastern Radiological Health Laboratory (SERHL), PHS, and are similar to those employed for the Radiation Surveillance Network before July 31, 1967. The air sampling station locations are shown in figure 5.

The gross beta radioactivity is determined by cutting a 2-inch diameter disk from each sample which is then counted in a thinwindow, gas-flow, anticoincidence G-M counter. The detector is calibrated with a strontium–90-yttrium–90 standard. The limit of detectability for a typical 24-hour sample is 0.001 pCi/m³.

The November 1967 air monitoring results from the participating countries are given in table 4.

Figure 5. Pan American Air Sampling Program stations

Table 4. Gross beta radioactivity in surface air, PAHO November 1967

Station location	Number of samples	Gross beta radioactivity (pCi/m³)		
		Maximum	Minimum	Average [a]
Argentina: Buenos Aires	13	0.11	0.04	0.07
Bolivia: La Paz	20	.04	.01	.02
Chili: Santiago	30	.07	.02	.04
Colombia: Bogota	20	.01	.00	.01
Ecuador: Guayaquil	28	.07	.02	.04
Jamaica: Kingston	22	.05	.01	.02
Peru: Lima	16	.08	.04	.05
Venezuela: Caracas	19	.02	.00	.00
West Indies: Trinidad	18	.03	.00	.01
Pan American summary	186	0.11	0.00	0.03

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values of less than 0.005 pCi/m³ are reported and used in averaging as 0.00 pCi/m³.

5. Fallout in the United States and Other Areas, January–June 1967 [1]

Health and Safety Laboratory
U.S. Atomic Energy Commission

Monthly fallout deposition rates for strontium–90 are determined by the Health and Safety Laboratory (HASL) for 49 sites in the United States and 107 locations in other countries. HASL data from all of the active United States stations and other selected points in the Western Hemisphere (figure 6) covering the period from January through June 1967, are summarized in tables 5 and 6. All the stations of the 80th Meridian Network are represented.

Methods of collection

Two methods of fallout collection are employed by HASL. In the first, precipitation and dry fallout are collected for a period of 1 month in a stainless-steel pot with an exposed area of 0.076 m². At the end of the collection period, the contents are transferred, by careful scrubbing with a rubber spatula, to a polyethylene sample bottle which is then shipped to the laboratory for analysis.

The second method involves the use of a polyethylene funnel, with an exposed area of 0.072 m², attached to an ion exchange column. After a 1-month collection, the inside of the funnel is wiped with a tissue, and the tissue is inserted in the end of the column, which is then sealed and sent to HASL for analysis. It has been shown that at the 95-percent confidence level there was no significant difference in the strontium–90 measurements obtained from samples collected by the two methods (*1*).

Laboratories at Westwood, N. J., New York City, N. Y., and Seattle, Wash., have analyzed monthly precipitation samples for other radionuclides. The amount of precipitation at each station and the monthly deposition rates for iron–55, strontium–90, cerium–144, plutonium–238, and plutonium–239 –240, at each station are presented in table 7.

[1] The data in this article were taken from "Fallout Program Quarterly Summary Report," HASL 184:A–4 to A–170; B–1 to B–22.

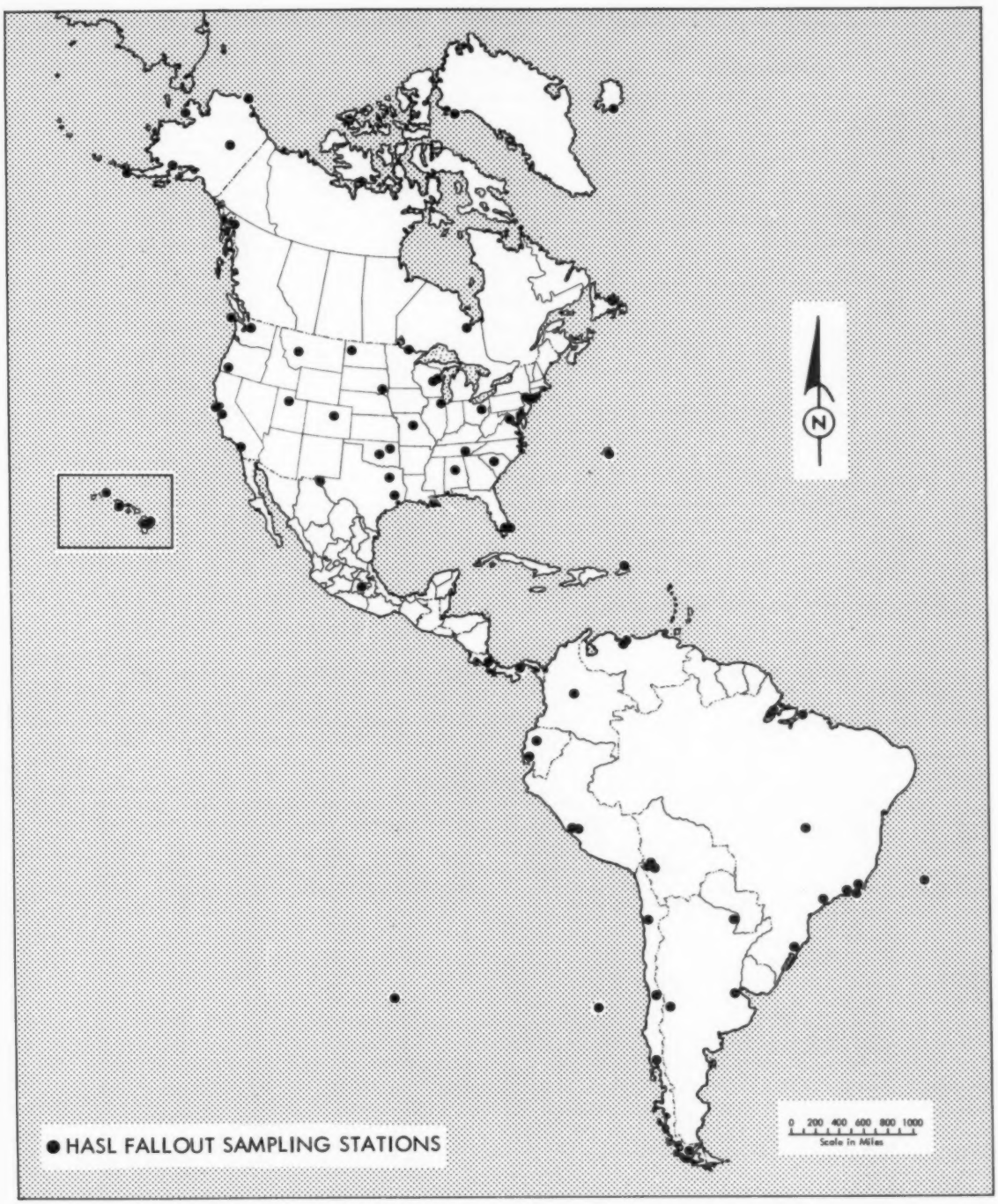

Figure 6. HASL fallout sampling stations in the Western Hemisphere

Table 5. Strontium–90 fallout in the United States, HASL, January–June 1967

Sampling location		Type of collection	Deposition (nCi/m²)					
			Jan	Feb	Mar	Apr	May	June
Ala:	Birmingham	pot	0.09	0.16	0.08	0.13	0.16	0.10
Alaska:	Anchorage	column	.02	.03	.04	.04	.07	.08
	Barrow	column	.01	.01	.02	.01	.01	.02
	Cold Bay	column	.07	.09	.04	NS	.14	.16
	Fairbanks	column	.02	.01	.02	.01	.05	.07
	Juneau	column	.21	.03	.05	.10	.03	NS
	Nome	column	NS	NS	NS	NS	.04	.02
Calif:	W. Los Angeles	pot	.15	.03	.13	.16	.02	.01
	San Francisco	column	.22	.02	.16	.14	.02	.04
Colo:	Denver	column	.05	.09	.02	.18	.24	.16
Fla:	Coral Gables	pot	.05	.03	.16	.01	.09	NS
	Miami	column	.07	.03	.09	.04	.04	.13
Hawaii:	Hilo	column	.28	.34	.31	.53	.20	.19
	Honolulu	pot	.03	.49	.14	.13	.27	.12
	Lihue	column	.17	.12	.13	.15	.08	.05
	Mauna Loa	column	.03	.01	.06	.05	.04	.01
Ill:	Argonne	pot	.06	.05	.28	.21	.12	.13
La:	New Orleans	column	.06	.06	.07	.04	.10	.05
Minn:	International Falls	column	.04	.02	.08	.18	.05	.15
Mo:	Columbia	column	.05	.04	.19	.21	.13	.11
Mont:	Helena	column	.02	.06	.06	.09	.04	.18
N.J.:	Westwood	pot	.12	.06	NS	NS	NS	NS
N.Y:	New York City	pot	.16	.11	.17	.24	.31	.13
N. Dak:	Williston	column	.02	.01	.04	.14	.02	.12
Ohio:	Wooster	pot	.04	.04	.09	.01	.01	.22
Okla:	Tulsa	pot	.04	.07	.11	.17	.25	.13
Ore:	Medford	column	.09	.07	.06	.08	.09	.05
S.C:	Columbia	column	.11	.14	.08	.15	.20	.09
S. Dak:	Vermillion	pot	.06	.02	.07	.06	.25	.41
Tex:	Dallas	column	.02	.07	.08	.14	.19	.10
	El Paso	column	.01	.02	.03	.02	.02	.03
	Houston	column	.04	.02	.04	.07	.04	.01
Utah:	Salt Lake City	pot	.28	.13	[a].20	[a].20	.22	.28
Va:	Sterling	column	.05	.04	.12	.06	.18	.05
Wash:	Seattle	pot	.11	.13	.18	NS	NS	NS
	Seattle	pot	.20	.07	.16	.10	.06	.07
	Forks	column	NS	NS	.40	.19	.08	.03
Wis:	Green Bay	column	.04	.01	.09	.23	.12	.20

[a] Indicates proportioned from originally consolidated data.
NS, no sample reported.

Table 6. Strontium–90 fallout in North and South America, HASL, January–June 1967

Sampling location		Type of collection	Deposition (nCi/m²)					
			Jan	Feb	Mar	Apr	May	June
Argentina:	Buenos Aires	column	0.13	0.11	0.05	0.05	0.03	0.04
	Formosa	column	.07	.03	.02	.01	.03	.03
	Malargue	column	.02	.01	.03	.01	.01	NS
Bahamas:	Bimini	column	.04	.02	.04	.01	.04	.17
Bermuda:	Kindley AFB	column	.05	.11	.10	.17	.10	.07
Bolivia:	Chacaltaya	column	.02	.02	.02	.01	.01	.01
	La Paz (city)	column	.02	.02	.01	.01	.01	.01
	La Paz (Ovejuyo)	column	.03	.02	.01	.01	.02	.02
Brazil:	Belem	column	.04	.04	.05	NS	NS	.02
	Brasilia	pot	NS	NS	NS	NS	NS	NS
	Itaici Sao Paulo	pot	NS	NS	NS	NS	NS	NS
	Nova Friburgo	pot	.07	.03	.03	.01	NS	NS
	Rio de Janeiro	column	.04	NS	NS	NS	NS	NS
	San Jose Dos Compos	pot	.01	NS	NS	NS	NS	NS
	Sao Leopoldo	pot	.26	.11	.15	.01	NS	NS
	Trindade Island	column	.05	.02	.03	.01	NS	NS
Canada:	Moosonee	column	.01	.01	.05	.08	.05	.07
Canal Zone:	Balboa	column	.02	.02	.02	.07	.04	.01
Chile:	Antofagasta	column	.01	NS	NS	NS	NS	NS
	Isla Robinson Crusoe[a]	column	[b].04	NS	NS	NS	NS	NS
	Easter Island	column	[b].03	[b].03	.02	.04	.02	NS
	Puerto Montt	column	NS	.08	.08	.05	.13	NS
	Punta Arenas	column	.04	.03	.04	.02	.06	NS
	Santiago	pot	.01	.01	.01	.03	.03	.03
	Santiago	column	.01	.01	.02	.01	.07	.04
Colombia:	Bogota	pot	[c]T	.01	NS	NS	NS	NS
Costa Rica:	Turrialba	column	.02	.01	.02	.02	.04	.02
Equador:	Guayaquil	column	NS	.03	.01	.01	.01	NS
	Quito	column	.03	.01	.01	.01	.01	.01
Greenland:	Thule	column	.01	.01	.01	.01	.05	NS
Iceland:	Keflavik	column	.07	.12	.06	.11	.06	NS
Mexico:	Mexico City	column	.02	.01	.01	.03	.05	.03
Peru:	Lima	column	.02	NS	NS	.01	NS	NS
	Lima	column	.02	.44	.01	.01	.01	NS
Puerto Rico:	San Juan	column	.04	.06	.06	.04	.05	.06
Venezuela:	Caracas (site 1)	column	.02	.02	.02	.04	.02	.01
	Caracas (site 2)	column	.01	.01	.02	.02	.02	.03

[a] Isla Alejandro Selkirk.
[b] Indicates proportioned from originally consolidated data.
[c] T, trace or zero.
NS, no sample reported.

Table 7. Radiochemical analyses of precipitation samples at 3 U.S. sites, HASL January–June 1967

	Jan	Feb	Mar	Apr	May	June
Precipitation (cm)						
N. J.: Westwood	4.29	6.48	NS	NS	NS	NS
N. Y.: New York City	3.53	6.81	15.16	8.76	10.36	11.78
Wash.: Seattle	18.72	4.62	7.87	NS	NS	NS
Iron-55 (nCi/m³)[a]						
N. J.: Westwood	1.25	0.66	NS	NS	NS	NS
Wash.: Seattle	1.22	NS	NS	NS	NS	NS
Strontium-90 (nCi/m³)[b]						
N. J.: Westwood	0.12	0.06	NS	NS	NS	NS
N. Y.: New York City	0.16	0.11	0.17	0.24	0.31	0.13
Wash.: Seattle	0.11	0.13	0.18	NS	NS	NS
Cerium-144 (nCi/m³)[b]						
N. J.: Westwood	NS	NS	NS	NS	NS	NS
Wash.: Seattle	0.81	0.64	0.40	NS	NS	NS
Plutonium-238 (nCi/m³)						
N. Y.: New York City	0.00014	0.00020	0.00034	0.00154	0.00091	0.00057
Wash.: Seattle	0.0001	0.0014	0.0011	NS	NS	NS
Plutonium-239–240 (nCi/m³)						
N. Y.: New York City	0.00167	0.00192	0.00199	0.00519	0.00306	0.00129
Wash.: Seattle	0.0006	0.0009	0.0002	NS	NS	NS

[a] Decay corrected to 10/15/61.
[b] Decay corrected to midpoint of sampling month.
NS, no sample reported.

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SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included here are such data as those obtained from human bone sampling, bovine thyroid sampling, Alaskan surveillance and environmental monitoring around nuclear facilities.

Environmental Levels of Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission receives from its contractors semiannual reports on the environmental levels of radioactivity in the vicinity of major AEC installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational Safety in directives published in the AEC Manual.[1]

Summaries of data from the environmental radioactivity monitoring reports follow for the Argonne National Laboratory, Atomics International, Feed Materials Production Center, and the National Reactor Testing Station.

[1] Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation" contains essentially the standards published in Chapter 0524 of the AEC Manual.

1. Argonne National Laboratory January–June 1967 [2]

University of Chicago
Lemont, Illinois

The radioactivity of the environment is determined on a continuing basis by measuring the radioactivity in naturally-occurring materials collected both on and off the Argonne National Laboratory site. Since radioactivity is usually spread by air and water, the environmental monitoring program at Argonne has concentrated on these materials. The sampling locations discussed in this report are shown in figures 1 and 2.

[2] Summarized from "Environmental Radioactivity at Argonne National Laboratory, January–June 1967," University of Chicago, Lemont, Ill.

Air monitoring

Air-filter samples were collected continuously at seven locations on the Argonne site and at five locations off the site. The alpha and beta radioactivity in air filter samples are summarized in table 1. The alpha radioactivity concentrations were normal both on and off the site and in the range found in previous years. The beta radioactivity was presumed to result from fission and neutron-activation products from nuclear detonations. Fission products following the Chinese nuclear test of December 28, 1966 were present in air and precipitation beginning January 2, 1967. The short-lived fission products from this source decayed with time as expected and had essentially disappeared by the end of June 1967. The December 1966 test contributed about 0.1 pCi/m^3 to the

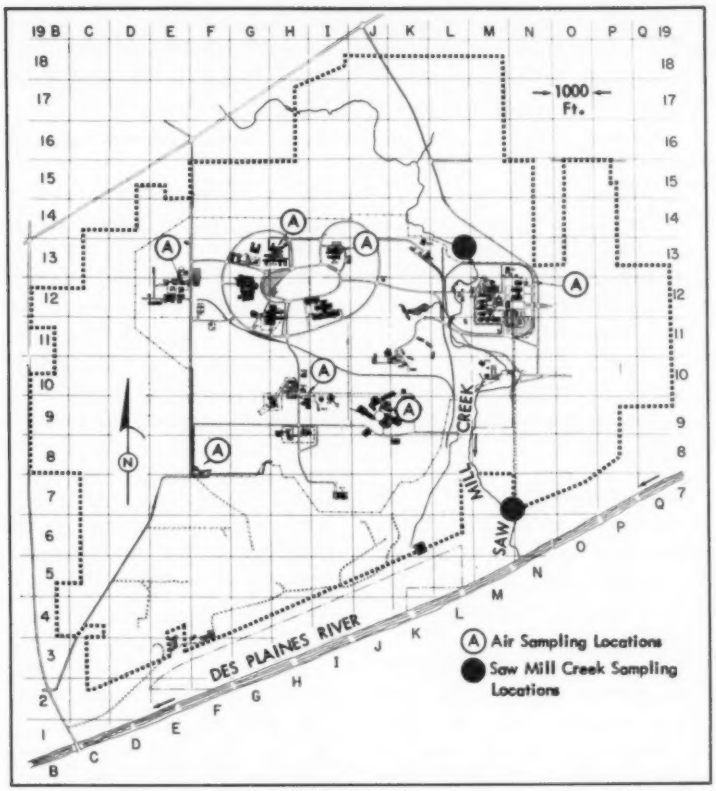

Figure 1. Sampling locations on the site of Argonne National Laboratory

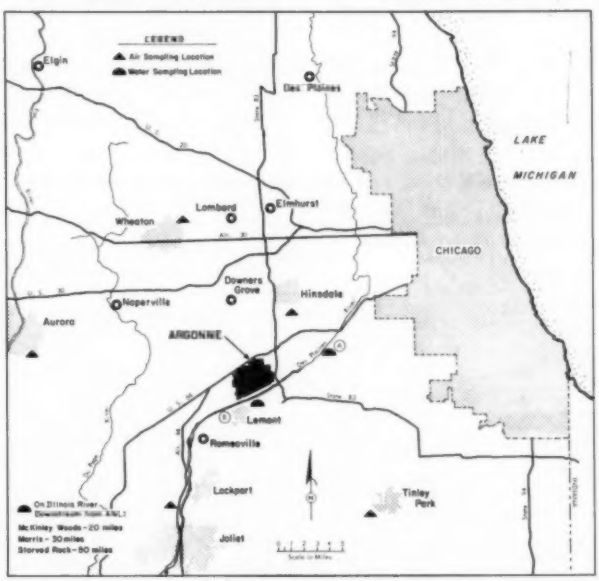

Figure 2. Site location of Argonne National Laboratory (including some offsite sampling stations)

Table 1. Alpha and beta radioactivity in air-filter samples[a] Argonne, January–June 1967

Period	Location	Number of samples	Alpha radioactivity (pCi/m^3) multiply by 10^{-2}			Beta radioactivity (pCi/m^3)		
			Average	Minimum	Maximum	Average	Minimum	Maximum
January	onsite	26	0.45	0.27	0.60	0.45	0.10	1.14
	offsite	23	.47	.21	.78	.46	.12	1.45
February	onsite	25	.40	.27	.53	.15	.10	0.27
	offsite	20	.39	.25	.54	.15	.09	.26
March	onsite	27	.44	.25	.74	.14	.09	.20
	offsite	22	.43	.27	.84	.15	.11	.23
April	onsite	23	.37	.21	.53	.15	.05	.22
	offsite	20	.50	.28	.77	.18	.03	.33
May	onsite	26	.46	.23	.83	.11	.06	.21
	offsite	23	.53	.33	.87	.12	.09	.21
June	onsite	24	.42	.20	.77	.06	.04	.09
	offsite	22	.42	.30	.76	.06	.03	.11
January–June	onsite	151	0.42	0.20	0.83	0.18	0.04	1.14
	offsite	130	0.46	0.21	0.87	0.19	0.03	1.45

[a] These results were obtained by measuring the samples 4 days after they were collected in order to avoid counting the natural radioactivity due to radon and thoron decay products.

average airborne beta radioactivity of 0.19 pCi/m^3 during the first half of 1967. Fallout levels were approximately the same as during 1966. The Chinese nuclear test of June 17, 1967, did not produce a detectable quantity of fallout in the air samples.

Sampling on charcoal for gaseous radioiodine was conducted continuously on the ANL site only. Iodine–131 was present only in trace amounts during the first and second week of January. This radioactivity followed the Chinese nuclear test of December 1966.

Water monitoring

Argonne wastewater is discharged into Sawmill Creek, a stream that runs through the Argonne grounds and enters the Des Plaines River about 500 yards downstream from the wastewater discharge. Sawmill Creek was sampled above and below the discharge to evaluate the effect of the wastewater on the radioactivity in the creek. The sampling locations are shown in figure 2.

Below the wastewater outfall the creek was usually sampled three times weekly. Since it was impractical to analyze all the samples for all the nuclides and elements desired, equal portions of the three samples collected each week were combined and analyzed. The results obtained in this way represent the average concentrations in the weekly samples. Additional samples were collected when unusual amounts of radioactivity were expected or found in the wastewater. Above the site,

Table 2. Non-volatile alpha and beta radioactivity in Sawmill Creek water, Argonne, January–June 1967

Month	Location[a]	Number of samples	Alpha radioactivity (pCi/liter)			Beta radioactivity (pCi/liter)		
			Average	Minimum	Maximum	Average	Minimum	Maximum
January	Upstream	2	3.9	2.6	5.3	21	15	26
	Downstream	9	1.7	1.6	1.9	15	11	20
February	Upstream	2	2.3	1.7	2.8	15	13	18
	Downstream	12	3.1	0.3	4.8	40	30	49
March	Upstream	2	2.1	2.1	2.2	8.7	7.5	9.9
	Downstream	15	2.5	1.7	4.2	21	11	52
April	Upstream	1	----------	----------	2.3	5.5	3.0	7.9
	Downstream	15	1.7	1.4	1.9	12	9.8	14
May	Upstream	2	1.3	1.0	1.5	6.6	6.3	7.4
	Downstream	12	2.3	.9	4.3	34	12	86
June	Upstream	2	1.5	.9	2.1	9.3	5.9	13
	Downstream	15	1.2	.8	1.4	18	8.7	26
January–June	Upstream	11	2.2	0.9	5.3	11	3.0	26
	Downstream	78	2.1	0.3	4.8	23	8.7	86

[a] Relative sampling location with respect to Argonne wastewater outfall (figure 1).

samples were collected at weekly intervals, and at least one sample each month was analyzed for each radioactive nuclide of interest. The total alpha and beta radioactivities found in Sawmill Creek during the first half of 1967 are given in table 2.

Upstream from the Argonne site the alpha radioactivity was due primarily to radioactive nuclides that occur naturally in the stream. Any additional radioactivity below the wastewater outfall was due to alpha-emitting nuclides present in the waste water. The concentration of alpha radioactivity in the creek resulting from the presence of Argonne wastewater can be estimated as follows. Below the outfall, the natural creek water was diluted approximately in half by Argonne waste water. Consequently, the average natural alpha radioactivity in the creek below the outfall was approximately one-half of the above-site radioactivity, or about 1.1 pCi/liter, and the average radioactivity due to waste water was about 1.1 pCi/liter. This is the same as the corresponding 1966 average.

The alpha-particle emitters most likely to be present in Argonne waste water are isotopes of uranium, plutonium, and thorium. The alpha radioactivity in the creek water due to these elements are summarized in table 3. Comparison of these concentrations with the total alpha radioactivity indicates that most of the alpha radioactivity added to the creek in Argonne waste water was due to uranium. The uranium concentrations above the site were normal. Below the outfall, the waste water added an average of about 1.2 pCi of uranium per liter of waste water or 0.003 percent of the AEC radiation protection standard. The average plutonium and thorium concentrations above and below the outfall were less than the minimum detectable amount.

In addition to the natural beta radioactivity in the creek, beta radioactivity from nuclear detonations was detected at both sampling locations and beta radioactivity from Argonne wastewater was found in some samples below the outfall. The natural beta radioactivity concentration is approximately 5 pCi/liter above the site and 3 pCi/liter below the site. The Argonne contribution to the total beta radioactivity below the outfall during the first half of 1967 is estimated to be approximately 15 pCi/liter, compared to 45 pCi/liter in 1966 and 5 pCi/liter in 1965. The remaining radioactivity at both locations, about 5 pCi/liter, was due to fallout. The concentrations of fallout radioactivity was about the same as that found during 1966.

Since Sawmill Creek empties into the Des Plaines River, which in turn flows into the Illinois River, the radioactivity in the latter two streams is important in assessing the contribution of Argonne wastewater to the environmental radioactivity. The Des Plaines River was sampled monthly above the mouth of Sawmill Creek and weekly below, to determine if the radioactivity in the creek had any effect on the radioactivity in the river. The total radioactivity is summarized in table 4. The concentrations were similar at both locations except for two samples, collected in January and February below the mouth of Sawmill Creek, that contained abnormally high concentrations of beta radioactivity (49 and 66 pCi/

Table 3. Alpha-emitting elements in Sawmill Creek water Argonne, January–June 1967

Element	Location[a]	Number of samples	Concentration (pCi/liter)			Average as a percent of AEC standard[b]
			Average	Minimum	Maximum	
Uranium	Upstream	12	1.7	0.8	3.2	0.004
	Downstream	81	2.1	0.8	4.4	0.005
Plutonium	Upstream	6	—	—	<0.05	—
	Downstream	39	<0.05	<0.05	0.10	<0.001
Thorium	Upstream	6	—	—	<0.05	—
	Downstream	39	—	—	<0.05	—

[a] Relative sampling location with respect to Argonne waste water outfall (figure 1).
[b] AEC radiation protection standards—uranium, 4 x 10^4 pCi/liter, plutonium, 5 x 10^3 pCi/liter.

Table 4. Average radioactivity in Des Plaines and Illinois River water, Argonne, January–June 1967

Location	Concentration (pCi/liter)		
	Non-volatile alpha radioactivity	Non-volatile beta radioactivity	Uranium
Des Plaines River[a] (above Sawmill Creek)	2.7	17	1.9
Des Plaines River[b] (below Sawmill Creek)	2.6	17	1.9
Illinois River[c]	1.8	11	2.2

[a] Sampled near Route 45, upstream from the mouth of Sawmill Creek.
[b] Sampled near Lemont, downstream from the mouth of Sawmill Creek.
[c] One sample collected at McKinley Woods State Park, on June 8, 1967.

liter). These samples contained the same mixture of fission products found in air. Since they were collected when fallout following the December 1966, Chinese test was at a high level, the excess beta radioactivity is probably due to fallout. Samples were not obtained above the site on the 2 days when high beta radioactivity was found in below-site river water.

The Des Plaines River samples were also analyzed for uranium and the alpha-particle emitting isotopes of plutonium and thorium. All results were normal and similar to those found earlier. The uranium concentrations averaged 1.9 pCi/liter at both locations. Plutonium was not detected at either location and thorium was found in two below-site samples at concentrations of 0.07 and 0.06 pCi/liter, respectively. The detection limit for plutonium and thorium is 0.05 pCi/liter.

The Illinois River was sampled at McKinley Woods on June 8, and the alpha and beta radioactivity concentrations, 1.8 and 11.0 pCi/liter, respectively, were normal and similar to those found in other nearby streams at that time. No radioactivity originating at Argonne was detected in the Des Plaines or Illinois Rivers.

Radioactivity in milk

Raw milk was collected monthly from a local diary farm and analyzed for several fission products. Barium–140, strontium–89, and iodine–131 were not present in concentrations greater than the minimum detectable amounts of 20 pCi/liter for iodine–131 and 3 pCi/liter for the other two radionuclides. The cesium–137 and strontium–90 concentrations are given in table 5. These two nuclides are long-lived fission products from past nuclear tests and their presence in milk is not related to Argonne operations. Concentrations were similiar to those found during the first half of 1966 and no correlation with fallout from the December 1966 test was apparent or expected since the maximum fallout occurred when the cows were on winter feed.

Table 5. Fission product concentrations in milk, Argonne, January–June 1967

Date collected	Concentrations (pCi/liter)	
	Cesium-137	Strontium-90
January 11	70	5.5
February 8	72	9.0
March 2	65	9.2
April 11	87	7.7
May 1	92	9.6
June 21	102	6.6
Average	81	7.9

Recent coverage in *Radiological Health Data and Reports*:

Period	Issue
January–June 1966	March 1967
July–December and annual summary 1966	September 1967

2. Atomics International January–June 1967 [3]

North American Aviation, Inc.
Canoga Park, California

Atomics International, a division of North American Aviation, Incorporated, has been engaged in atomic energy research and development since 1946. The company designs, develops, and constructs nuclear reactors for central station and compact power plants and for medical, industrial, and scientific applications.

The company headquarters is located in Canoga Park, Calif., approximately 23 miles northwest of downtown Los Angeles. The 290-acre Nuclear Development Field Laboratory (Santa Susana Facility), equipped with extensive testing facilities for the support of advanced nuclear studies, is in Ventura County in the Simi Hills approximately 29 miles northwest of downtown Los Angeles. The location of the above sites in relation to nearby communities is shown in figure 3.

The basic concept of radiological hazard control at Atomics International encourages total containment of radioactive materials, and through rigid operational controls, minimizes effluent releases and external radiation levels. The environmental monitoring program provides a check on the effectiveness of radiological

[3] Summarized from "Environmental Monitoring, Semiannual Report, January 1, 1967 to June 30, 1967," Atomics International, Division of North American Aviation, Inc.

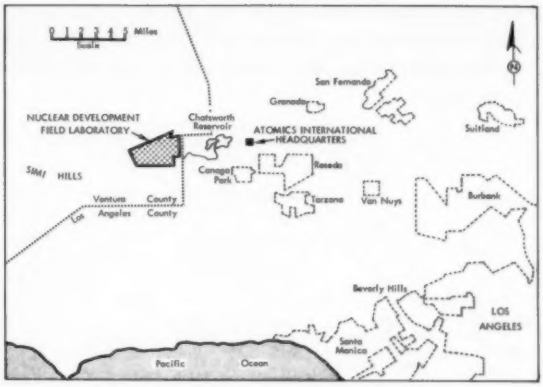

Figure 3. Atomics International facilities and vicinity

safety procedures and of engineering safeguards incorporated into facility design.

The environs of Atomics International headquarters and Nuclear Development Field Laboratory (NDFL) are surveyed monthly to determine the concentration of radioactivity in typical surface soil, vegetation, and water samples. In addition, continuous environmental air monitoring at the sites provides information concerning airborne particulate radioactivity.

Air monitoring

Environmental air sampling is conducted continuously at the headquarters and NDFL sites with automatic air samplers operating on 24-hour sampling cycles. Airborne particulate radioactivity is collected on HV–70 filter paper which is automatically changed at the end of each sampling period. The filter is removed from the sampler and counted after the radioactivity is allowed to decay for at least 72 hours. The volume of a typical daily environmental air sample is approximately 20 cubic meters. The average concentration of long lived beta-gamma radioactivity on airborne particulates is presented in table 6 for 1966 and the first half of 1967.

Table 6. Beta-gamma radioactivity of airborne particulates, 1966 and January–June 1967

Location	Calendar year 1966		January-June 1967	
	Number of samples	Average concentration (pCi/m^3)	Number of samples	Average concentration (pCi/m^3)
Headquarters	706	0.18	353	0.68
NDFL	2,205	0.17	1,243	0.66

Water monitoring

Process water used at the NDFL is obtained from Ventura County Water District No. 10 and distributed onsite by the same piping system previously used when process water was supplied by onsite wells. Pressure is provided by elevated storage tanks, one 50,000-gallon and one 500,000-gallon tank onsite. While clinically potable, the water is not used for drinking. Bottled potable water is delivered by a vendor and is not analyzed. Water from the pipe system is sampled monthly at two locations. The average process water radioactivity concentration is presented in table 7.

Table 7. Process water radioactivity NDFL site 1966 and January–June 1967

Type of radioactivity	Calendar year 1966		January-June 1967	
	Number of samples	Average concentration (pCi/liter)	Number of samples	Average concentration (pCi/liter)
Alpha	24	0.13	12	0.09
Beta-gamma	24	4.6	12	3.4

Water samples are also collected monthly at Chatsworth Reservoir which is operated by the Los Angeles City Department of Water and Power. Normally, one water sample is obtained from the lake surface and a second sample is obtained from the reservoir water supply inlet located on the north side of the lake. The average radioactivity for both surface and supply water samples is presented in table 8.

Table 8. Chatsworth Reservoir water radioactivity 1966 and January–June 1967

Sample	Type of radioactivity	Calendar year 1966		January-June 1967	
		Number of samples	Average concentration (pCi/liter)	Number of samples	Average concentration (pCi/liter)
Lake surface	Alpha	12	0.32	6	0.29
	Beta-gamma	12	5.9	6	8.7
Supply inlet	Alpha	12	0.42	6	0.26
	Beta-gamma	12	5.9	6	6.5

Surface discharged waters from NDFL facilities drain into holding reservoirs on adjacent property. When full, the main reservoir is drained into Bell Creek, a tributary of the Los Angeles River in the San Fernando Valley,

Los Angeles County. Pursuant to the requirements of Los Angeles Regional Water Quality Control Board Resolution 66–49 of September 21, 1966, an environmental sampling station has been established in Bell Creek Canyon approximately 3.4 miles downstream from the south NAA boundary. Samples obtained and analyzed monthly, include stream-bed mud, vegetation, and water. Average radioactivity concentrations in the main holding reservoir and Bell Creek samples are presented in table 9.

Table 9. Radioactivity in the Main Holding Reservoir [a] and Bell Creek, Atomics, January–June 1967

Sample description (units)	Number of samples	Alpha radioactivity	Beta radioactivity
Reservoir Station 6[a] (pCi/liter)	6	0.20	5.8
Reservoir Station 12[a] (pCi/liter)	5	.09	6.5
Bell Creek mud (pCi/g)	6	.38	24
Bell Creek vegetation (pCi/g ash)	6	.32	240
Bell Creek water (pCi/liter)	6	.05	7.3

[a] Locations not shown on figure 3.

Soil and vegetation monitoring

Soil and vegetation are regularly sampled at 24 locations. Twelve sampling stations are located within the boundaries of Atomics International's sites and are referred to as "onsite" stations. The remaining 12 stations, located within a 10-mile radius of the sites, are referred to as "offsite" stations.

Surface soil types available for sampling range from decomposed granite to clay and loam. Samples are taken from the top half-inch layer of ground surface. The soil samples are packaged and sealed in plastic containers and returned to the laboratory for analysis. Radioactivity in soil samples is presented in table 10.

Table 10. Radioactivity in the soil, Atomics 1966 and January–June 1967

Area	Type of radioactivity	Calendar year 1966		January–June 1967	
		Number of samples	Average concentrations (pCi/g)	Number of samples	Average concentration (pCi/g)
Onsite	Alpha	144	0.41	72	0.40
	Beta-gamma	142	29	72	27
Offsite	Alpha	48	0.44	24	0.37
	Beta-gamma	48	25	24	25

Vegetation samples obtained in the field are of the same plant type wherever possible, generally sunflower or wild tobacco plant leaves. These types maintain a more active growth rate during the dry season than do most natural vegetation indigenous to the local area. Vegetation leaves are stripped from plants and transferred to the laboratory for analysis. Plant root systems are not routinely sampled. Radioactivity in vegetation samples is presented in table 11.

Table 11. Radioactivity in vegetation, Atomics 1966 and January–June 1967

Area	Type of radioactivity	Calendar year 1966		January–June 1967	
		Number of samples	Average concentration (pCi/g ash)	Number of samples	Average concentration (pCi/g ash)
Onsite	Alpha	144	0.37	72	0.49
	Beta-gamma	144	169	72	425
Offsite	Alpha	48	0.37	24	0.33
	Beta-gamma	48	123	24	658

3. Feed Materials Production Center January–June 1967 [4]

National Lead Company
Fernald, Ohio

The Feed Materials Production Center (FMPC) is operated by the National Lead Company of Ohio for the AEC. The location as related to populated areas is shown in figure 4. Cincinnati and Hamilton, the larger nearby communities, are situated 20 and 10 miles from the center, respectively. Operations at this project deal with the processing of high-grade uranium ores and ore concentrates to produce metallic uranium and with fabricating the metal into fuel elements.

During the many involved reactions and processes that lead to the production of reactor fuels, various liquid and airborne wastes are generated. These wastes contain varying quantities of uranium. Various in-plant methods are used to curtail their release into the environment surrounding the plant. Almost complete

[4] Summarized from "Feed Materials Production Center Environmental Monitoring Semiannual Report for the First Half of 1967" (NLCO–1002).

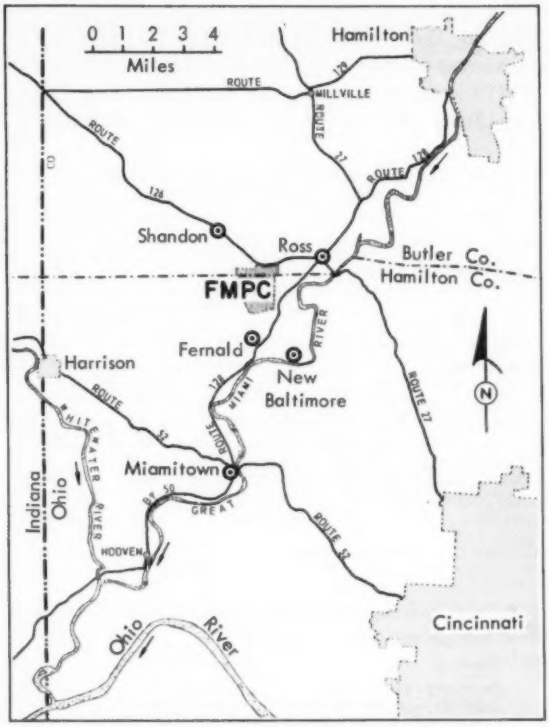

Figure 4. Area map of Feed Materials Production Center

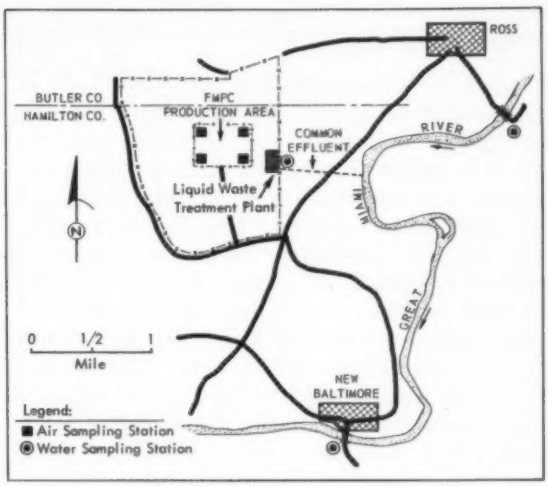

Figure 5. Air and water sampling stations, FMPC

removal of the materials is accomplished by using dust collectors and waste-treatment processes. In order to determine what concentrations reach the area surrounding the project an environmental survey program has been established which consists of water, soil, and air sampling of the environs and performing those analyses on the samples that are indicative of material released from the plants.

Onsite air samples are obtained from four permanent perimeter air sampling stations, located at the four corners of the production area as shown in figure 5. Samples from these perimeter stations are collected once each week and analyzed for uranium and total radioactivity. Offsite samples are collected by a mobile air sampling unit. The location at which samples are collected is determined by local meteorological conditions on the day of sampling. Approximately 20 percent of all samples are taken upwind of the FMPC plant. Replicate samples are taken at each sampling point and averaged to obtain a representative concentration for that location. Concentrations of uranium and total radioactivity of airborne particulates sampled at onsite and offsite locations are given in table 12.

Table 12. Radioactivity levels of airborne particulates, FMPC, January–June 1967

Location	Number of samples	Uranium concentration[a] (pCi/m³)			Total radioactivity[b] (pCi/m³)		
		Maximum	Minimum	Average	Maximum	Minimum	Average
Onsite:							
Southwest	26	0.4	<0.1	0.1	1.1	<0.1	0.3
Northwest	26	.1	<.1	<.1	0.7	<.1	0.2
Northeast	26	.5	<.1	.1	1.1	.1	0.4
Southeast	26	.3	<.1	<.1	.6	<.1	0.2
All onsite samples	104	0.5	<0.1	0.1	1.1	<0.1	0.3
Offsite:							
0–2 miles from FMPC	27	.5	<.1	.1	1.1	<.1	0.2
2–4 miles from FMPC	48	.3	<.1	<.1	4.4	<.1	0.4
4–8 miles from FMPC	28	.1	<.1	<.1	9.7	<.1	1.4
8–12 miles from FMPC	12	<.1	<.1	<.1	5.1	<.1	1.1
All offsite samples	115	0.5	<0.1	<0.1	9.7	<0.1	0.7

[a] AEC radiation protection standard, 2 pCi/m³.
[b] AEC radiation protection standard, 100 pCi/m³.

Water monitoring

Each of the individual production plants on the project has collection sumps and treatment equipment to remove the uranium from the process waste water. The effluent from the plants are collected at a general sump for equalization and settling. The clear water from the sump is pumped to the river. The solid portion is pumped to a chemical waste pit for further settling. The flow, which is decanted to the clear-well portion of the pit, is virtually free of solids and radioactivity. The effluent from the sump and clear well are combined with waste water from the FMPC water treatment plant, sanitary sewage treatment plant, and storm sewerage system and discharged via a common effluent outfall into the Great Miami River. A weir-type water sampler collects samples of the combined effluent stream, which are removed and analyzed daily. These results are utilized with measurements of river flow in calculating the radioactive contaminant concentrations added to the river. Weekly spot samples are also obtained upstream and downstream from the common FMPC effluent at locations shown in figure 5. The results of the FMPC water monitoring program for January–June 1967 are summarized in table 13.

Table 13. Radioactivity in the Great Miami River FMPC, January–June 1967

Location	Number of Samples	Uranium concentration[a] (pCi/liter)			Total radioactivity[b] (pCi/liter)		
		Max.	Min.	Average	Max.	Min.	Average
Sewer outfall	181	<10	<10	<10	40	<10	<10
Upstream from outfall	26	<10	<10	10	120	<10	30
Downstream from outfall	29	140	<10	12	340	<10	40

[a] AEC radiation protection standard, 20,000 pCi/liter.
[b] AEC radiation protection standard, 3,000 pCi/liter.

Recent coverage in *Radiological Health Data and Reports*:

Period	Issue
January–June 1966	April 1967
July–December 1966	August 1967

4. National Reactor Testing Station[5] January–June 1967

Idaho Operations Office-Health Services Laboratory
U.S. Atomic Energy Commission
Idaho Falls, Idaho

Data from the environmental monitoring network on and around the National Reactor Testing Station (NRTS) in eastern Idaho revealed that NRTS operations during the first half of 1967 did not contribute significantly to environmental radiation or radioactivity concentration levels. These levels remained well below the levels defined as thresholds of concern by the Federal Radiation Council (FRC). The radiation protection standards used at the NRTS, which are established in AEC Manual Chapter 0524, are based on FRC recommendations. In choosing applicable standards for drinking water, credit has been taken for the fact that no significant quantities of radium–226 or radium–228 have been released to the environs by NRTS operations. The concentrations of radioactivity reported include contributions from all sources. No attempt has been made to separate radioactivity contributed by NRTS operations from that contributed by natural sources of radioactivity or by fallout from weapons debris. Samples of air, water, and milk are collected routinely at stations shown in figure 6. The results of the analyses performed on these samples are shown in table 14.

Offsite water monitoring

Low-level wastes from various operating facilities at the NRTS are released to the groundwater table through disposal wells and ponds located near each facility. Before disposal the liquid wastes are carefully monitored at the

[5] Summarized from "Environmental Monitoring Report No. 20, First and Second Quarter 1967" U.S. Atomic Energy Commission, Idaho Operations Office, Health and Safety Division, National Reactor Testing Station.

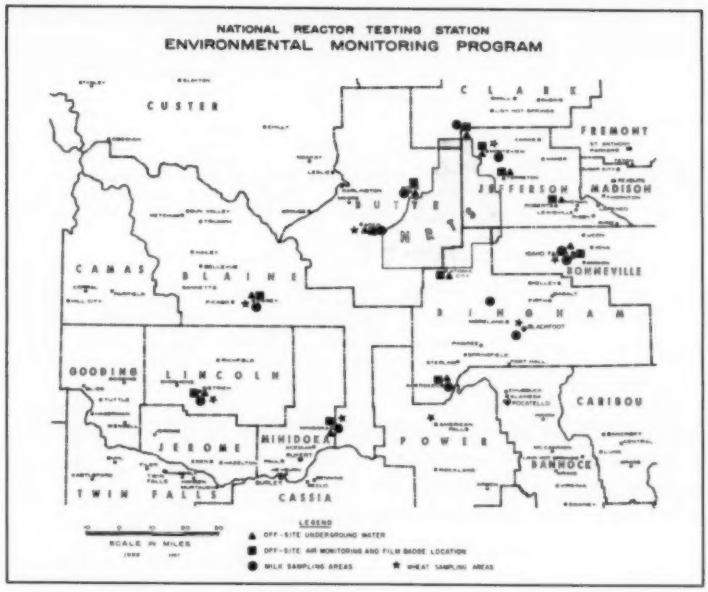

Figure 6. Environmental monitoring stations, National Reactor Testing Station

NRTS and, as an added safeguard, offsite underground water samples are collected and analyzed regularly from those populated areas nearest the site boundaries. Samples from these locations, as shown on the accompanying map, plus the onsite samples provide adequate information on the underground water leaving the NRTS. During January–June 1967, one sample was collected from each of 12 sampling stations. The average concentrations of alpha and beta-particle emitters were less than 4 percent and 8 percent of the respective radiation protection standards. The alpha radioactivity is attributed primarily to radioactive elements which are naturally present in the environment.

Onsite water monitoring

Onsite samples were taken from the plant production wells in order to detect and define possible sources of contamination. During January–June 1967, 205 samples were collected from 22 sampling stations, most on a biweekly basis. Analyses of these samples showed that average concentrations of alpha and beta-particle emitters were no more than 0.1 percent and 0.3 percent of their respective AEC standards.

Air monitoring

During January–June 1967, 207 air samples were collected and evaluated for airborne alpha-particle emitters. A gross alpha-particle determination was made on filter-paper samples after a sufficient time had elapsed to permit the decay of the short-lived daughter products of radon and thoron. The filter-paper samples were counted for alpha-particle emission by scintillation counters. The average measured concentrations of alpha radioactivity in air was .002 pCi/m^3 or 5 percent of the AEC standard. The radiation protection standard used is that for uncontrolled areas and for gross alpha radioactivity for which no analysis for specific isotopes have been made. The alpha radioactivity is attributed primarily to long-lived radioactive elements naturally present in the environment.

Results of the data reported from the 12 offsite radiation telemetry stations indicate

Table 13. Environmental monitoring data for the National Reactor Testing Station January–June 1967

Type of sample and units	Number of stations	January-June 1967					
		Approximate frequency of collection	Type of analysis	Minimum level of detection	Maximum radioactivity of single sample	Average radioactivity per sample	AEC radiation protection standard
Offsite underground water, (pCi/liter)	12	Semiannual	Alpha	3	5	<4	100
			Beta	6	15	<8	100
Onsite production well water, (pCi/liter)	22	Biweekly	Alpha	3	9	<4	3,000
			Beta	6	13	<7	3,000
Offsite air, (pCi/m³)	12	Continuous	Beta-gamma	1.6	16	<3	100
			Iodine-131	3.6	24	<4	100
Offsite milk, (pCi/liter)	12	Monthly	Iodine-131	20	49	<21	100
			Strontium-90	1.5	8	<6	200
Offsite area monitoring badges, (mR)		Semiannual	Gamma	10	70	<48	170/yr

that the average concentrations of gaseous iodine–131 and particulate gross beta radioactivity in the atmosphere were less than 6 percent of the AEC radiation protection standards.

Offsite milk monitoring

Routine analyses of iodine–131 and strontium–90 concentrations in milk continued during January–June 1967. Of the 72 routine radioiodine analyses, only 4 samples were found to have concentrations greater than 20 pCi/liter. As indicated in table 14, the average iodine–131 levels do not exceed 21 percent of the AEC standard. Strontium–90 concentrations in 12 samples showed the maximum radioactivity to be 8 pCi/liter or 4 percent of the AEC standard with an average value of less than 6 percent of this standard.

Gamma radiation levels

Seminannual measurements of external gamma radiation levels were made with thermoluminescent dosimeters (TLD) at 12 offsite locations during the first half of 1967.

Natural background radiation levels at TLD locations vary, but studies made prior to nuclear operations at the NRTS showed that normal background levels were of the order of 100–150 mR/yr. This indicates that NRTS operations have added no significant radiation to surrounding areas.

Recent coverage in *Radiological Health Data and Reports*:

Period	Issue
January–June 1966	March 1967
July–December 1966 and calendar year 1966	September 1967

Reported Nuclear Detonations, February 1968

The U.S. Atomic Energy Commission announced two underground nuclear tests conducted at its Nevada Test Site during February 1968.

The test of February 21 was a low-intermediate yield test (equivalent to 20 to 200 kilotons of TNT). An underground nuclear test of low yield (less than 20 kilotons TNT equivalent) was conducted on February 29, 1968.

SYNOPSES

Synopses of reports, incorporating a list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip them for their files.

POLONIUM–210 IN TOBACCO. *Stuart C. Black and Erich W. Betthauer. Radiological Health Data and Reports, Vol. 9, March 1968,* pp. 145–152.

Variations of polonium–210 content in tobacco, the amount of polonium–210 in various fractions of smoked cigarettes and changes in polonium–210 content of mainstream smoke caused by variation in the smoking procedure have been determined. The average polonium–210 content for whole cigarettes was found to be 0.483 pCi/gram and 0.477 pCi/gram for butts. No polonium–210 enrichment in the butt of cigarettes during smoking was found. Polonium–210 content and concentration in mainstream smoke increases with puff size.

KEYWORDS: cigarettes, mainstream smoke, polonium–210, puff size, smoking machine, tobacco.

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March 1968

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